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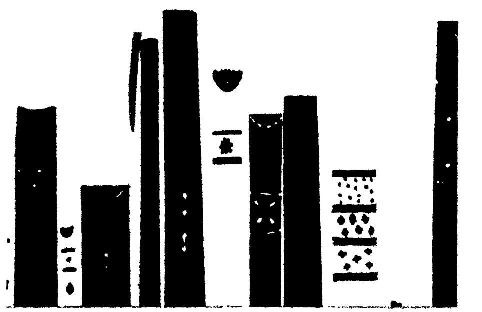

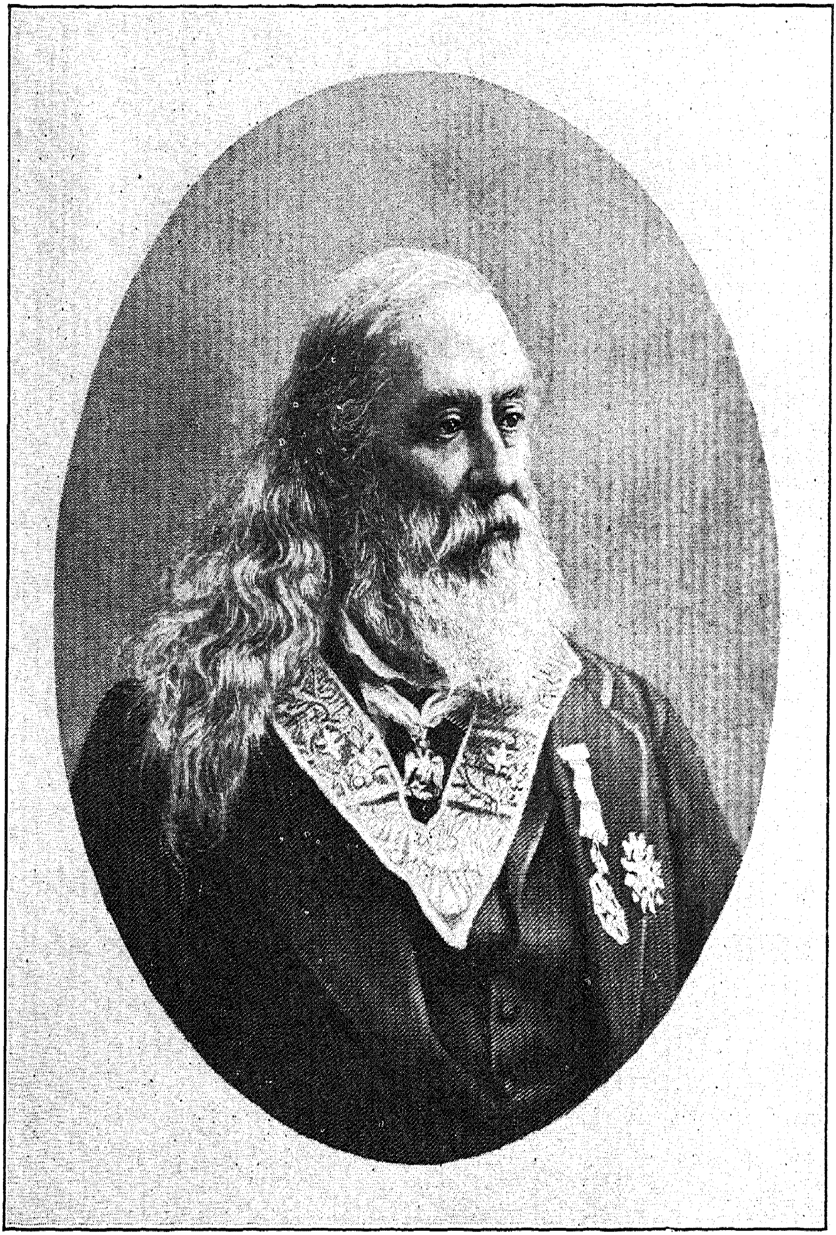

Albert Pike

BIBLIOGRAPHY of the WRITINGS OF ALBERT PIKE

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By

WILLIAM L. BOYDEN, 33° HON.

Librarian of the Supreme Council 33°

WASHINGTON

1921

ALBERT PIKE.

Albert Pike, son of Benjamin and Sarah (Andrews) Pike, was born in Boston, Massachusetts, December 29, 1809. About four years afterward his father removed to Newburyport in the same State. Here the child grew to manhood, getting the usual education of the times in the common schools, supplemented by a few terms at a private school in the same town and at the academy in Framingham.

He began to teach school at the age of fifteen and when he was sixteen, he passed an examination for and entered the freshman class at Harvard. Owing to the straitened circumstances of his family, it was necessary for him to earn the money to pay for his board and tuition, which he did by teaching during the fall and winter at Gloucester. He fitted himself while teaching to enter the junior class in the fall of 1826 and passed the necessary examination, but owing to a misunderstanding with the faculty regarding his tuition fees he returned home and educated himself, going through the prescribed course of studies for the junior and senior years while teaching. He taught in Fairhaven and afterward as assistant and principal in the grammar school at Newburyport, and then for several years in a private school in the latter town, until March, 1831.

In the spring of 1831 he started for the west walking much of the way, and for the next few years traveled, explored, traded and lived among the indians, learning their language and customs, and by his honest and straightforward association with them, gained a confidence which thirty years afterwards, during the great Civil War, made him so useful and powerful among them for the cause of the Confederacy which he espoused.

He finally settled in Little Rock in 1833, and it was there that he became editor of the Arkansas Advocate, studied law and wrote for some of the magazines. His series of poems entitled "Hymns to the Gods," which were written earlier, he sent to the editor of Blackwoods Magazine, John Wilson (Christopher North), who published them about 1838, pronouncing him "The coming poet of America" and remarking that "These fine hymns entitle their author to take his place in the highest order of his country's poets" and that "His massive genius marks him to be the poet of the Titans."

He was a Captain of Cavalry in the Mexican War, where he served with distinction, participating in the battle of Buena Vista and afterwards riding a distance of five hundred miles, from Saltillo to Chihuahua, through a country swarming with the fugitive soldiers from Santa Anna's defeated armies, with only forty-one men of his command, receiving the surrender of the city of Mapini on the way.

About 1851 he transferred the practice of law from Little Rock to New Orleans, practicing also before the Supreme Court of the United States, returning in 1857 to Little Rock, where he remained until the

outbreak of the Civil War, when he served as commissioner for negotiating treaties with the indians and as Brigadier General in the Confederate States.

After the war he resided in Memphis, Tennessee for several years, moving to Washington about 1869, where he resided for the remainder of his life. His death occurred on April 2, 1891, in his eighty-second year.

He joined Freemasonry in 1850 and in less than nine years became the highest ranking officer in this institution, becoming Grand Commander of the Supreme Council of the 33rd degree for the Southern Jurisdiction of the United States, which is the "Mother Supreme Council of the World."

As a lawyer he was one of the foremost jurists of his day. As a scholar, philosopher, poet and master of languages, he ranked with the most eminent, and as a soldier and statesman his ability was unquestioned. He has been called "The Homer of America" and "The Zoroaster of modern Asia."

It is an interesting fact and significant of the man that he never published any book for sale. With the exception of his legal briefs, whatever he had printed was done at his own expense for private circulation, or was donated to the Supreme Council of the 33rd degree over which he presided for about thirty years.

His versatile mind, genius, and tremendous energy are best illustrated by a perusal of the following bibliography.

WM. L. BOYDEN.

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Signed: Pike & Cummins, solicitors.

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Signed: Pike & Cummins, attorneys for the appellants. In the copy before us "Pike & Cummins" is ruled out and "Albert Pike" written in in his own hand.

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Signed: Albert Pike, solicitor for appellant.

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Signed: Albert Pike, counsel for Wynn.

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Signed: Pike & Cummins.

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Signed: Albert Pike, counsel for the appellees.

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Signed: Pike & Cummins, counsel for appellants.

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Signed: Albert Pike, attorney for Henry M. Rector.

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Signed: Pike & Cummins, attorneys for plaintiff.

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Signed: Pike & Cummins, counsel for Hill and others.

Jones, Stephen M., appellant vs. Joseph I. Andrews, Pinckney Reed and H. W. Bryson, appellees. Supreme Court of the United States. No. 221. From the circuit court of the United States for the district of West Tennessee. Argument for the appellees. Albert Pike, Robert W. Johnson, of counsel. [N. p., about 1866?] 25p. 8°.

Lawson, Jas. & L. Chase, appellees, advs. The Bank of the State of Arkansas, appellant. In the Supreme Court of Arkansas. No.------, January term, 1854. Appeal from Pulaski circuit court. Printed by Stillwell & Wassell, [Little Rock, Ark.] 4p. 8°.

Signed: Pike & Cummins.

McCarron, Thomas, appellant vs. Thos. Cassidy, appellee. In the Supreme Court of Arkansas, July term, 1855. Appeal from Sebastian circuit court in chancery. Printed by J. D. Butler, Little Rock, Ark. 22p. 8°.

Signed: Pike & Cummins for the appellee.

McPherson vs. Cox. On motion for new trial. [Washington? about 1873?] 14p. 8°

Signed: Albert Pike, L. H. Pike, of counsel for defendant.

McPherson, John D., appellant vs. Mary A. Cox. In the Supreme Court of the United States. At the term of 1877-78. No. 199. Brief of appellee. [Washington, D. C.] 112p. 8°.

Signed: Albert Pike, Robert W. Johnson, L. H. Pike, of counsel for the appellee.

Marshall and wife, et al. vs. Hewes Scull, et al. In the Supreme Court of Arkansas. No.------, January term, 1854. Appeal from the Jefferson circuit court. Printed by Stillwell & Wassell, Little Rock,Ark. 14p. 8°.

Signed: Pike & Cummins, counsel for defendants.

Mimmack, Bernard P. vs. The United States of America. Supreme Court of the United States. Term of 1878-1879. No. 73. Appeal from the Court of Claims. [Washington, D. C.] 26p. 8°.

Signed: Albert Pike, Luther H. Pike, of counsel.

Moore & Gail, adms. of Irwin vs. G. Blackmore, et al. In the Supreme Court of Arkansas. No.------, July term, 1853. Appeal from Phillips circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 9p. 8°.

Signed: Pike & Cummins, solicitors.

Muscogee or Creek nation of indians, Memorial of, to the Congress of the United States. [N. p., about 1852?] 24p. 8°.

Signed: Albert Pike, attorney of the Creek nation.

Newman, Mary Jane vs. Horace B. Allis. In the Supreme Court of Arkansas. No.------, July term, 1853. Appeal from Pulaski circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 11p. 8°.

Signed: Pike & Cummins and P. Trapnall, attornies.

On the question Damni et interesse; on the question of domicil. N. p. N. d.

Signed: "Albert Pike, Robert W. Johnson, of counsel for claimants." Pp. 19-32 of a legal case, the particulars of which are not now obtainable.

Patterson, E. G., plaintiff in error vs. The Commonwealth of Kentucky. In the Supreme Court of the United States. Term of 1878-1879. No. 117. Brief of defendant in error. Albert Pike, Robert W. Johnson, Luther H. Pike, of counsel. Washington, Jos. L. Pearson, printer, 1878. 7p. 8°.

Pettit & Ford vs. Abner Johnson, et al. In the Supreme Court of Arkansas. No------January term, 1854. Appeal from Chicot circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 11p. 8°.

Signed: Albert Pike, counsel for Pettit & Ford.

Phelps, Calvin vs. John Henry, et al. In the Supreme Court of Arkansas. No------, January term, 1853. On appeal from Crawford circuit court, in chancery. Printed by John M. Butler, Little Rock, Ark. 19p. 8°.
Signed: Pike & Cummins.

Phillips, James, appellee vs. The St. Louis Perpetual Insurance Co., appellant. In the Supreme Court of Louisiana. Argument for the appellant. J. B. Steel, print., 60 Camp st.[New Orleans? about 1854?] 28p. 8°.
Signed: Hunton & Pike, counsel for appellants.

Pillow, Jerome B., plaintiff in error vs. Truman Roberts, defendant in error. Supreme Court of the United States. December term, 1851. In error from the circuit court for the Eastern District of Arkansas. [N. p. N. d.] 61p. 8°.
Signed: Albert Pike, attorney for plaintiff in error.

Rector, Elias vs. A. Morehouse. In the Supreme Court of Arkansas. No------, July term, 1854. Appeal from Pulaski circuit court. Printed at the True Democrat Office, [Little Rock, Ark.] 9p. 8°.
Signed: Pike & Cummins, attorneys for plaintiff.

Rector, Henry M. vs. The United States and others. Supreme Court of the United States. No. 646. Argument upon the claim under the New Madrid location. For the claimant, Rector, Pike & Johnson, Canborn & King, of counsel for Henry M. Rector. [N. p. N. d.] 176p. 8°.

Rector, Henry M., appellant vs. The United States and others. Supreme Court of the United States. Term of 1875-6. No. 646. Brief for appellant. Albert Pike, Robert W. Johnson, John B. Sanborn, Charles King, of counsel for Rector. [Washington, D. C.] 70p. 8°.

Ringgold vs. Patterson. In the Supreme Court of Arkansas. No------, January term, 1854. Appeal from Independence circuit court. Printed by Stillwell & Wassell, [Little Rock, Ark.] 25p. 8°.
Signed: Pike & Cummins & W. Byers, attorneys.

Roane, Julia, executrix vs. Ann E. Rivers, complainant. In the Supreme Court of Arkansas. No. 176. January term, 1854. Appeal from Jefferson, in chancery. Printed by Stillwell & Wassell, [Little Rock, Ark.] 12p. 8°.
Signed: Curran & Gallagher and Pike & Cummins.

Roberts, Joseph, appellant vs. William Totten, appellee. Supreme Court of Arkansas, January term, 1852. On appeal from the circuit court of Pulaski county. Appellee's argument, on petition for reconsideration. [Printed at the office of the Arkansas Whig, Little Rock, Ark.] 14p. 8°.
Signed: Pike & Cummins.

Russell, William vs. Buchanan & Cady. In the Supreme Court of Arkansas. No------, July term, 1853. Appeal from Pulaski circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 4p. 8°.
Signed: Pike & Cummins, counsel for appellant.

Ryburn, Benj. F. vs. Edward L. Pryor. In the Supreme Court of Arkansas. No------, January term, 1853. Appeal from Hempstead circuit court. Printed by John M. Butler, Little Rock, Ark. 23p. 8°.
Signed: Albert Pike, attorney for appellee.

Sessions, Richard R., Daniel A. Sessions and Sanford C. Faulkner, appellants vs. John M. Pintard, appellee. On appeal. In the Supreme Court of the United States, at December term, 1854. From the circuit court of the United States for the Eastern District of Arkansas. Printed by Stillwell & Wassell, Little Rock, Ark. 8p. 8°.

Signed: Albert Pike, counsel for appellants.

Sullivan, Lee, vs. James Hadley, et al. In the Supreme Court of Arkansas. No. . . . , January term, 1854. Printed by Stillwell & Wassell [Little Rock, Ark.] 8 p. 8°.

Signed: Pike & Cummins.

Taylor, Frederic, dec'd, Pre-emption claim of. Argument for the claim. [N. p., about 1846?] 7p. 8°.

Signed: Albert Pike, att'y for Taylor's administrator.

[Tennessee, Legislature of, vs. Citizens of.] In the Supreme Court of the United States. ---------- Term, A. D. 18----. Argument for----. Albert Pike, Robert W. Johnson, advocates. 68p. 8°.

Texas, State of, complainant vs. George W. White, John Chiles, and others, defendant. Original suit: No. 6. In the Supreme Court of the United States, December term, 1868. In equity. Argument for John Chiles, defendant. By Albert Pike and Robert W. Johnson, and James Hughes, Esqs. [Washington, D. C.] 96p. 8°.

In the copy in the Library of the Supreme Council at Washington, is the following in Pike's own hand: "Prepared for James Hughes without charge, out of professional courtesy. Albert Pike."

Thorn, Thomas, In re the creditors of. Bill of the trustees of the Real Estate Bank. In the Supreme Court of Arkansas. No.-------, July term, 1853. Printed by Stillwell & Wassell, Little Rock, Ark. 19p. 8°.

Signed: Albert Pike, counsel for trustees R. E. Bank.

Todd, William H., as assignee of the claim of A. D. Kelly & Co., and creditor of the succession of Junius W. Craig, deceased vs. Joseph S. Woodfolk, Lucy D. Woodfolk, and others, claiming with himself, creditors of the succession of Junius W. Craig, deceased. In the chancery court of Louisville, State of Kentucky. Upon the marshalling of the assets in Kentucky. Argument of Albert Pike, of counsel for William H. Todd. [N. p., about 1861?] 19p. 8°.

Tucker, Philip C., and Robert Pulsford, appellants vs. N. A. Cowdrey, the Galveston, Houston and Henderson Railroad Company, and others, appellees. Supreme Court, U. S. Term of 1870-71. No. 212, included in No. 119. Argument for appellants. Albert Pike, Robert W. Johnson, of counsel for appellants. [Washington, D. C.] 79p. 8°.

The United States vs. James L. Dawson. Supreme Court of the United States, December term, 1853. On certificate of division of opinion from the circuit court of the Eastern District of Arkansas. Gideon, print. [Washington, D. C.] 18p. 8°.

Signed: Albert Pike, counsel for James L. Dawson.

Very, Martin, appellant vs. Jonas Levy, appellee. Supreme Court of the United States, December term, 1851. No. 130. Appeal from the circuit court for the State of Arkansas. Argument for the appellee. [Little Rock, Ark., 1852.] 15p. 8°.

Signed: Albert Pike, solicitor for the appellee.

Walker, David, et al. vs. John Drennen, et al. Crawford circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 23p. 8°.

Signed: Pike & Cummins, counsel for Drennen and others.

Walker, John W., as Com'r of 16th Sec., appellant vs. R. C. Byrd, J. Robins and A. Pike, surv. appellees. In the Supreme Court of Arkansas. No.------, January term, 1854. Appeal from Pulaski circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 7p. 8°.

Signed: Pike & Cummins, counsel for appellees.

Wallach, Richard L., and others, appellants vs. John Van Riswick, appellee. Supreme Court of the United States. Term of 1874-5. No. 275. Brief for the appellants. Pike & Johnson, of counsel. Washington, D. C. Printed by W. H. Moore, 511 Eleventh street, 1974. 92p. 8°.

Cover title used.

Wallach, Richard L., and others, appellants vs. John Van Riswick, appellee. In the Supreme Court of the United States. Term of 1875-6. No. 62. Brief for the appellants, in reply. Albert Pike, Robt. W. Johnson, L. H. Pike, of counsel. [Washington, D. C.] Printed by W. H. Moore, 511 Eleventh street, 1875. 16p. 8°.

West, Hector R, et al, appell'ts vs. Jos. R. Williams, et al., appellees, and Jos. R. Williams, et al., appell'ts vs. Hector R. West, et al., appellees. In the Supreme Court of Arkansas. No.------, July term, 1853. Cross appeals from Pulaski circuit court, in chancery. Printed by Stillwell & Wassell, Little Rock, Ark. 24p. 8°.

Signed: Pike & Cummins.

Woodruff, Wm. E. vs. Wm. McD. Pettit. In the Supreme Court of Arkansas. No.------, July term, 1853. Error to Pulaski circuit court. Printed by Stillwell & Wassell, Little Rock, Ark. 6p. 8°.

Signed: Pike & Cummins, counsel for Pettit.

Worthington, E. vs. E. Curd & Co. In the Supreme Court of Arkansas. No.------, January term, 1854. Appeal from Chicot circuit court. Printed by Stillwell Wassell, [Little Rock, Ark.] 18p. 8°.

Signed: Pike & Cummins.

Wynn, William vs. Josiah Garland. In the Supreme Court of Arkansas. No.------, July term, 1852. Bill for title to the N. E. ¼ sec. 18. T. 16 S: R. 1 W. Printed by John M Butler, Little Rock, Ark. 119p. 8°.

Signed: Albert Pike, solicitor for Wynn.

Wynn, William vs. Chesley B. Morris, et al. In the Supreme Court of the United States. No.------, December term, 1855. Error to the Supreme Court of Arkansas. Argument for William Wynn. John Wassell, printer, Little Rock, Ark. 90p. 8°.

Signed: Albert Pike, counsel for Wynn.

Wynn, William vs. Wm. F. Morris and Keziah Taylor. In the Supreme Court of Arkansas. No.------, July term, 1853. Printed by Stillwell & Wassell, Little Rock, Ark. 38p. 8°.

Signed: Albert Pike, counsel for Wynn.

MILITARY

Address. To the senators and representatives of the State of Arkansas in the congress of the Confederate States. 20p. 8°.

Signed: Albert Pike, Louisiana, 20th March, 1863.
Relates to charges and specifications preferred against Major General Thomas C. Hindman.

Battle of Pea Ridge, or Elkhorn Tavern, March 6, 1862. By Brig. Gen. Albert Pike. *In* La Bree. The Confederate soldier in the Civil War, p. 64-67.

Charges and specifications preferred August 23, 1862, by Brigadier General Albert Pike, against Major General Thomas C. Hindman. Richmond, Va. 1863. 13p. 8°.

Letter to the President of the Confederate States. Fort McCulloch. Choctaw nation. July 3, 1862. 3p. 8°.

A circular letter signed: "Albert Pike," regarding Maj. Gen. Thos. C. Hindman.

Maxims of Military Science and Art. *See* Manuscripts.

Muster roll of Capt. Albert Pike's Company. *See* Manuscripts.

NEWSPAPERS.

The Arkansas Advocate. Little Rock, Arkansas.

Pike was Associate Editor in 1834, and Editor and owner from April 10, 1835 to April 20, 1837.

The Memphis Appeal. Memphis, Tennessee.

Pike was Editor-in-Chief about 1867-1868.

The Patriot, Washington, D. C.

Pike was Associate Editor 1868-1870.

POLITICAL AND ECONOMIC.

Address by the President [Albert Pike] of the State Counsil of Arkansas, [American Party,] delivered at the first annual session, on the 30th April, 1855. Published by direction of the State Council. Little Rock, Ark., J. M. & J. D. Butler, printers, 1855. 15p. 8°.

Address on the Southern Pacific Railroad, delivered in the hall of the House of Representatives of the State of Louisiana. By Albert Pike. February 9, 1855. New Orleans, Emile La Sère, state printer, 1855. 21p. 8°.

Draught of a declaration of independence, proposed to the convention of the State of Arkansas, and withdrawn from its consideration. [By Albert Pike.] Little Rock, R. S. Yerkes & Co., printers, 1861. 13p. 8°.

The effect of pardons and amnesties. [N. p., 186—?] 11p. 8°

Signed: Albert Pike. Caption title used.

The emphatic remonstrance of the people of the State of Arkansas against invasion of their right of self-government; addressed to the representatives of the other United States of America, in congress assembled. [By Albert Pike.] [N. p., about 1873?] 6p. 8°. Caption title.

Indictment for treason. . . In the Circuit Court of the United States for the Eastern District of Arkansas. Albert Pike, defendant. [N. p., 1865.] 14p. 8°. Caption title.

Signed: Albert Pike.

Kansas State rights. An appeal to the democracy of the south. By a Southern State-Rights Democrat [Albert Pike.[Washington, Henry Polkinhorn, printer, 1857. 39p. 8°.

Albert Pike's letter addressed to Major Gen. Holmes. Little Rock, Arkansas, December 30, 1862. 1p. folio.

Printed on wall paper.

Albert Pike's letter addressed to Major General Holmes. Little Rock, Arkansas, December 30, 1862. 7p. 8°.

Second letter to Lieut. General Theophilus H. Holmes. [Richmond, 1863.] 20p. 8°.

A letter to the President of the United States. [By Albert Pike.] New York, C. S. Westcott & Co., printers, No. 79 John street, 1865. 19p. 8°.

Letters of safeguard (issued to indian tribes west of Arkansas, August 12, 1861). *In* Moore, Frank. The Rebellion Record, v. 3, p. 400-401.

Letters to the people of the Northern States. [N. p., 1856.] 35p. 8°.

Signed: A. P. Caption title used.

Letters to the people of the Northern States. [N. p., 1856.] 48p. 8°.

Signed: A. P.

National plan of an Atlantic and Pacific railroad, and remarks of Albert Pike, made thereon, at Memphis, November, 1849. Little Rock, Ark., Gazette and Democrat, print., [1849.] 16p. 8°. Caption title.

Order No....... Headquarters, Dep't Indian Territory, Fort McCulloch, July 17, 1862. [2]p. wide 8°. Caption title and lines.

Signed: "By order of Brigadier-General Albert Pike, commanding department of Indian Territory:: G. A. Schwarzman, Major and Assistant Adjutant-General." A sarcastic "order," prompted by conditions in his Department.

Overland route to the Pacific. [N. p., about 1857.] [1]+66p. 8°.

By a citizen of Arkansas: Albert Pike. Caption title used.

The past teaching the present and the future. *See* Manuscripts.

Southern and Western States Commercial Convention, Charleston, South Carolina. Journal of proceedings during the week, commencing Monday, April 10th, 1854.

Addresses and resolutions by Albert Pike, p. 36-39, 64-70, 83,84, 142-153, 157.

Southern and Western Convention, Charleston, 1854. Resolutions of the Charleston convention upon the subject of the Southern Pacific Railroad, adopted April, 1854 [and] A bill to create and incorporate the Southern Pacific Railroad. 17p. 8°.

Presented to the Legislature of the State of Louisiana, Feb. 7, 1855, by Albert Pike.

Southern Commercial Convention, New Orleans. Proceedings, January 8-15, 1855.

Addresses by Albert Pike, p. 5, 8-12, 16- 20.

Southern Commercial Convention, Savannah, Georgia, proceedings, December 8-12, 1856.

Debate by Albert Pike, p. 30-31, on slave trade, p. 39-40, on Southern Pacific Railroad.

State or province? Bond or free? Addressed particularly to the people of Arkansas. By. Albert Pike. [N. p.] 1861. 40p. 8°.

State or province? Bond or free? Appendix. By Albert Pike. [N. p.] 1861. 21p. 8°.

Thoughts on certain political questions. By a looker-on. [Albert Pike.] Washington, D. C. Geo. S. Gideon, printer, 1859. 104p. 8°.

To the American party South. Gideon, printer, 511 Ninth street, Washington, D. C. [1856.] 8p. 8°.

Signed: A. P.

To the people of Arkansas and California. [N. p., 1856.] 7p. 8°.

Signed: Albert Pike.

A treaty of friendship and alliance, made and concluded at the North Fork village, on the North Fork of the Canadian river, in the Creek nation, west of Arkansas, on the 10th day of July, 1861, between the Confederates of America, by Albert Pike, Commissioner . . . and the Creek nation of indians . . *In* Confederate States of America, Statutes at Large, Richmond, 1864, p. 289-310.

Treaty of friendship and alliance made and concluded at the North Fork village on the North Fork of the Canadian river, in the Creek nation, west of Arkansas, on the 12th day of July, A. D. 1861. By Albert Pike, Commissioner with plenary powers, of the Confederate States, and commissioners on the part of the Choctaw and Chickashaw nations. 25p. 8°.

Same in Confederate States of America, Statutes at large, Richmond, 1864, p. 311-331. Caption lines.

Same. Laws that united Choctaw and Chickashaw indians with the Confederacy. *In* Confederate Veteran, v. XI, no. 10, Nashville, Tenn., October, 1903, p. 449-458.

A treaty of friendship made and concluded at the Seminole Council House, in the Seminole nation, west of Arkansas, on the first day of August, 1861, between the Confederate States of America, by Albert Pike, Commissioner . . and the Seminole nation of red men. . . *In* Confederate States of America, Statutes at large, Rich. 1864, p. 332-346.

Treaty with the Comanches of the Prairies and Staked Plain. Articles of a convention entered into and concluded at the Wichita agency, near the False Washita river, in the country leased from the Choctaws and Chickashaws, on the 12th day of August, 1861, between the Confederate States of America, by Albert Pike, their commissioner . . . and the Ne-co-ni, Ta-ne-i-we, Co-cho-tih-ca and Ya-pa-rih-ca bands of the Ne-un or Commanches of the Prairies and Staked Plain. . . . *In* Confederate States of America, Statutes at large, Rich. 1864, p. 354-362.

Treaty with the Commanches and other tribes and bands. Articles of a convention entered into and concluded at the Wichita agency near the False Washita river, in the country leased from the Choctaws and Chickashaws, on the 12th day of August, 1861, between the Confederate States of America, by Albert Pike, their commissioner . . . and the Pen-e-tegh-ca band of the Ne-un, or Commanches, and the tribes and bands of Wichitas. . . . *In* Confederate States of America, Statutes at large, Rich. 1864, p. 347-353.

Treaty with the Osages. Articles of a convention entered into and concluded at Park Hill, in the Cherokee nation, on the 2nd day of October, 1861, between the Confederate States of America, by Albert Pike, their commissioner . . . and the great Osage tribe of indians. . . . *In* Confederate States of America, Statutes at large, Rich, 1864, p. 363-373.

Treaty with the Quapaws. Articles of a convention entered into and concluded at Park Hill, in the Cherokee nation, on the 4th day of October, 1861, between the Confederate States of America, by Albert Pike, their commissioner . . . and the Quapaw tribe of indians. *In* Confederate States of America Statutes at large, Rich. 1864, p. 386-393.

Treaty with the Senecas and Senecas and Shawnees. Articles of a convention entered into and concluded at Park Hill, in the Cherokee nation, on the 4th of October, 1861 between the Confederate States of America, by Albert Pike, their commissioner . . . and the Seneca tribe of indians, formerly known as the Senecas of Sandusky, and the Shawnees of the tribe or confederacy of Senecas and Shawnees of Lewistown, or the mixed bands of Senecas and Shawnees. *In* Confederate States of America, Statutes at large, Rich. 1864, p. 374-385.

Treaty with the Cherokees. October 7th, 1861. A treaty of friendship and alliance made and concluded at Tallequah, in the Cherokee nation . . . between the Confederate States of America, by Albert Pike, Commissioner with plenary powers, of the Confederate States. . . . 26p. 8° Caption title.

Same in Confederate States of America, Statutes at large, Rich., 1864, p. 394-411.

The true merits of the controversy in Arkansas for the consideration of honest men. By Pike & Johnson, attorneys and counsellors-at-law. Washington, 1874. 16p. 8°.

Contested election for the governorship of Arkansas, between Elisha Baxter and Joseph Brooks.

POETRY.

(Collected)

Prose sketches and poems, written in the Western country. By Albert Pike. Boston, Light & Horton, 1834. 200p. 12°.

The dedication to Joseph M. Titcomb, of Newburyport, Mass., is very interesting in view of the many books and pamphlets Pike afterwards issued. He says: "My dear friend: as a token of ancient fellowship and friendship, I beg you to allow me to dedicate to you what will probably be my last (as it is my first) attempt at authorship, in the shape of a book."

Nugae. By Albert Pike. Printed for private distribution. Philadelphia, C. Sherman, printer, 1854. 363p. 12°.

A collection of his poems. Preface states that only 150 copies are published for private distribution, "and shall never consent that they be published in any other way."

Hymns to the gods and other poems. Albert Pike. Privately printed. [New York? 1872.] 98p. 8°.

Rubricated title page.

Hymns to the gods and other poems. By Albert Pike. Privately Printed. Part I. [New York?] 1873. 98p. 8°.

Hymns to the gods and other poems. By Albert Pike. Privately printed. Part II. [New York?] 1882. 254p. 8°.

PartsI and II are always bound together.

Gen. Albert Pike's poems. With introductory biographical sketch by Mrs. Lilian Pike Roome, daughter of the author. Illustrated. Little Rock, Ark., Fred W. Alsopp, publisher, 1900. 532p. 8°.

Hymns to the gods and other poems. By Gen. Albert Pike. Edited by Mrs. Lilian Pike Roome, daughter of the author. Illustrated. Little Rock, Arkansas, Fred W. Alsopp, 1916, 269p. 12°.

Lyrics and love songs. By General Albert Pike. Edited by Mrs. Lilian Pike Roome, daughter of the author. Illustrated. Little Rock, Arkansas, Fred W. Alsopp, 1916. 246p. 12°.

(Individual)

Song: "After the midnight cometh morn." (For Seniorita Carolina Cassard.) [By Albert Pike.] [Washington?] January, 1870. [2]p. 8°.

Another edition, differing only in typography.
Same in Hallum, John. Biogrophical and pictorial history of Arkansas, p. 223. Masonic Review, v. 65, no. 2, Mar., 1886, p. 90. New Age Magazine, v. 21, no. 1, July, 1914, p. 16. Saunders & Davis. Gems of genius, p. 583.

All wait. *In* National Freemason, v. 8, no. 5, Feb. 2, 1867, p. 67. 2 stanzas of 9 lines each. First line: "Truth dawns upon the human soul." Same as his "Truth," which see. Not in any of his collected poems.

Ambition. *In* American Monthly Magazine, v. 2, no. 5, August, 1830, p. 305.

Signed: "P." An article "Dreams," just preceding the poem is signed: "A," i. e. Albert Pike. 58 lines. First line: "There came a dark vision among the thick stars." Not in any of hs collected poems.

Annie. *In his* Official Bulletins, v. 9, p. 177-178.

Ariel. *In* Boston Pearl, v. 5, no. 7, Oct. 31, 1835, p. 52.

Same in Hallum, John. Biographical and pictorial history of Arkansas, p. 227.

As the seasons come and go. [By Albert Pike.] [Washington?] September 6, 1875. [2] p. 8°.

Same in his Official Bulletins, v. 6, 451-452.

Auld lang syne. [By Albert Pike.] As sung at Jas C. McGuire's, January 8, 1869. [Washington? 1869.] [2]p. 8°.

Same in The Freemason (St. Louis), v. 5, no. 12, Dec. 1, 1871, p. 241. Library of Southern literature, v. 9, p. 4048-4049. Pike, Albert. Official Bulletins, v. 1, p. 544-545, and v. 6, p. 440-441. Texas Masonic Journal, Jan., 1885, p. 47.

An aunciente fytte pleasante and full of pastyme of a dollar or two. [By Albert Pike.] [Washington?] N. d. [3]p. 8°.

Autumn. *In* Boston Pearl, v. 5, no. 4, Oct. 10, 1835, p. 31.

Published in his collected poems as "Brown October."

Autumn. *In his* Official Bulletins, v. 7, p. 402-403.

The brave man. *In* Voice of Masonry, v. 27, no. 11, Nov., 1889, p. 993.

4 lines only

The brothers. *In* American Monthly Magazine, v. 1, uo. 11, Feb., 1830, p. 761-763.

Signed: "A. P." [Albert Pike.] 14 stanzas of 6 lines each. First line "Now night came down and the full moon beams." Not in any of his collected poems.

Buena Vista. *In his* Official Bulletins, v. 7, p. 517-519.

Also in Eggleston, Geo. C. American war ballads and lyrics, p. 151. Poetic and artistic masterpieces, p. 511. Rough and Ready Annual or Military Souvenir, p. 125.

Changes. *In* American Monthly Magazine, v. 2, no. 8, Nov., 1830, p. 548.

Signed: "P." March 6, 1830. 85 lines. First line: "Whence is the stream of years." Not in any of his collected poems.

Christmas. By Albert Pike. [Washington? about 187—.] [2]p. 8°.

Written originally in 1849.
Same in his Official Bulletins, v. 7, p. 515-516. *Also in* Keystone, The, v. 20, no. 26. Dec. 25, 1886, p. 205; Light (Topeka, Kan.), v. 2, no. 24, Dec. 15, 1886, p. 281; Voice of Masonry, v. 25, no. 1, Jan., 1887, p. 54.

Cleopatre. [By Albert Pike.] [Washington?] September 3, 1875. [2]p. 8°.

A conversation in the forest. *In* The Knickerbocker, v. 33, no. 5, May, 1849, p. 382-388.

Published in his poems as "An evening conversation."

Cruiskeen Lan. [By Albert Pike.] [Washington? about 1859.] [4]p. 8°.

Another edition. [By Albert Pike.] [Washington? about 1859.] [2] 8°.

The dead child. *In* Pope, W. F. Early days in Arkansas, p. 324.

Death in the desert. *In* Builder, The, v. 2, no. 5, May, 1916, p. 143.

A dirge. *In* Library of Southern literature, v. 9, p. 4057-4058.

Dissolution of the union. *In* The Ladies' Companion, v. 12, Jan., 1840, p. 141.

13 stanzas of 8 lines each. First line: "Down with the stars and stripes from out the sky!" This line does not indicate the tenor of the poem which is admonitory. These lines preface the poem: "The following stanzas were written at the time when the Confederacy seemed on the verge of dissolution. Happily there is no call for such language now; yet the publication of the verses may not be without benefit." Not in any of his collected poems.

Disunion. *In* The Knickerbocker, v. 35, no. 3, Mar., 1850, p. 241.

Dixie. *In* Brock, Sallie A. The Southern amaranth, p. 232.
Browne, F. F. Bugle echoes, p. 34.
Fagan, W. L. Southern war songs, p. 238.
Eggleston, George C. American war ballads and lyrics, p. 193.
Johnson, Helen K. Familiar songs, p. 580 (set to music).
Johnson, R. Campfire and battle field, p. 131.
Library of Southern Literature, v. 9, p. 4061.
Mason, Emily V. Southern poems of the war, various eds.

Moore, Frank. Anecdotes, poetry and incidents of the war, North and South, p. 94.

Moore, Frank. Rebel rhymes and rhapsodies, p. 20.

Moore, Frank. The Rebellion record, v. 1, p. 106.

Moore, Frank. Songs and ballads of the Southern people, 1861-65, p. 38.

Simms, W. G. War poetry of the South, p. 92.

Wharton, H. M. War songs and poems of the Southern Confederacy, 1861-65, p. 29.

The dying expression. *In* Boston Pearl, v. 4, no. 23, Feb. 14, 1835, p. 186.

Signed: "A. P." [Albert Pike.] 30 lines. First line: "Yes—death has set his fatal seal." Not in any of his collected poems.

Every year. By Albert Pike. [Washington? about 1872.] [3]p. 8°.

Every year. [By Albert Pike.] (A song old and new, the new in italic.) [Washington?] N. d. [2] p. 8°.

Of these two poems "Every year," the first has 7 stanzas of 8 lines each and the second, 8 stanzas of 8 lines each.

Same in Bromwell, J. H. Gems from the quarry, v. 2, p. 283. Hallum, John. Biographical and pictorial history of Arkansas, p. 225 James, J. G. Southern students handbook of selections for reading and oratory, p. 46-47. Library of Southern literature, v. 9, p. 4041-4043. One hundred choice selections, no. 17, p. 137. Perley, S. Poets of Essex county, Mass., p. 132-134. Pope, W. F. Early days in Arkansas, p. 321-323. Stedman & Hutchinson. Library of American Literature, v. 6, p. 489-490.

French and English text: La Chaine d'Union, v. 8, no. 11, Nov., 1879, p. 473. New Age Magazine, v. 21, no. 4, Oct., 1914, p. 156. Official Bulletins, by Pike, v. 4, p. 370-371. Voice of Masonry, v. 18, no. 5, May, 1880, p. 386.

Illustrated: Builder, The, v. 2, no. 1, June, 1916. Frontispiece. New Age Magazine, v. 2, no. 4, April, 1905, opp. p. 347. This poem is also found in nearly every masonic magazine published.

Fancies on fame. *In* The Ladies' Companion, v. 14, Nov., 1840, p. 41-42.

Fifteen stanzas of 8 lines each. First line: "Once more upon the ocean!" Not in any of his collected poems.

Fanny. *In* the Knickerbocker, v. 25, no. 5, May, 1845, p. 387.

Farewell to New England. *In* Duyckinck. Cyclopaedia of American Literature, v. 2, p. 521.

Fate of the presente. *In* Voice of Masonry, v. 34, no. 6, June, 1896, p. 467.

Tribute to Theodore Parvin, 33°. 8 lines. First line: "The past is the fate of the present." Not in any of his collected poems.

"The fine Arkansas gentleman." [By Albert Pike.] [Washington?] N. d. [4]p. 8°.

Same in The Ashlar, v. 5, p. 476.

The Freemason's son. *In* Mackey's National Freemason, v. 1, Dec., 1871, p. 126.

The New Age Magazine, v. 13, no. 1, July, 1910, p. 76.

Five stanzas of 8 lines each. First line: "The monarch's son may revel in." Used in the reception of a louveteau in the Scottish Rite. Not in any of his collected poems.

"God counts by souls." *In* New Age Magazine, v. 21, no. 4, Oct., 1914, p. 165.

Three stanzas of 16 lines each. First line: "Who shall judge a man from nature." Same as "An unpublished poem by Albert Pike." Not in any of his collected poems.

A holy house to build. *In* Builder, The, v. 1, No. 10, Oct., 1915, p. 231; v. 4, no. 10, p. 285.

Freemasons' Repository, v. 2, No. 15, Nov. 15, 1872.

Illinois Freemason, v. 4, no. 5, Jan. 20, 1889.

Keystone, The, v. 31, no. 29, Jan. 14, 1888, p. 225.

Light (Topeka, Kan.), v. 5. no. 11, July 20, 1889, p. 85.

Mackey's National Freemason, v. 1, Oct., 1871, p. 32.

Masonic Jewel, v. 2, no. 8, Aug., 1872, p. 124.

Masonic Journal (Louisville, Ky.), v. 2, no. 3, Feb. 1, 1877, p. 45.
Masonic Journal (Portland, Me.), v. 2, no. 6, May, 1889, p. 167.
Masonic Review, v. 50, no. 4, May, 1877, p. 175.
Masonic Trowel, v. 1, no. 9, March, 1888.
New Age Magazine, v. 16, no. 1, Jan., 1912, opp. p. 57.
Pike, Albert. Official Bulletins, v. 2, pa. 2, p. 231-232 and v. 8, p. 380.
Square and Compass, v. 14, no. 9, Nov., 1905, p. 250.

Three stanzas of 9 lines each First line: "We have a Holy House to build." Sometimes printed "The masons Holy House." Not in any of his collected poems. This poem is also found in nearly every other masonic magazine.

Hymn. *In* Boston Pearl, v. 5, no. 22, Feb. 13, 1836, p. 174.

Hymns to the gods. Bacchus. *In* American Monthly Magazine, v. 2, no. 8, Nov., 1830, p. 523.

Revised and published later in his series of "Hymns to the gods."

Hymns to the gods. Diana, Mercury. *In* American Monthly Magazine, v. 2, no. 7, Oct., 1830, p. 464.

Revised and published later in his series of "Hymns to the gods."

Hymns to the gods. *In* Blackwoods Magazine, v. 45, no. 284, June, 1839, p. 819-830. Griswold, R. W. Poets and poetry of America, p. 349-356. Knickerbocker, v. 35, nos. 4-6, April-June, 1850, p. 326, 443, 490.

An invitation. *In* Knickerbocker, v. 25, no. 3, Mar., 1845, p. 202.

Invocation. *In* Knickerbocker, v. 25, no. 5, May, 1845, p. 432.

Isadore, *In* Notes and Queries (Manchester, N. H.), v. 25, no. 6, June, 1907, p. 142.

Jordan is a hard road to travel. [By Albert Pike.] Sung at Jonah Hoover's, Feb. 18, 1869. [Washington.] Cunningham & M'Intosh, printers. [2]p. 8°.

A lament for Dixie. [By Albert Pike.] [Washington?] August, 1877. [3]p. 8°.

Legend of the wild hunter. *In* Boston Pearl, v. 5, Sep. 19, 1835, p. 3.

Published afterwards as "Legend of the wild rider," and as "The dead chase, a legend."

The light of days long past. [By Albert Pike.] [Washington.] Cunningham & M'Intosh, printers [About 1866.] [1]p. 8°. *Same in* Light, The, (Topeka, Kan.) v. 2, no. 6, March 15, 1886, p. 68. *Same in his* Official Bulletins, v. 7, p. 480. Voice of Masonry, v. 29, no. 5, May, 1891, p. 360.

Lines. *In* Boston Pearl, v. 5, no. 6, Oct. 24, 1835, p. 42

Seven stanzas of 7 lines each. First line: "The sea! the sea!" Not in any of his collected poems.

Lines to Boston. *In* The Ladies' Companion, v. 12, Dec., 1839, p. 87.

Fourteen stanzas of 8 lines each. First line: "Oh, Northern Athens, and Trimontane Gueen!" Not in any of his collected poems.

Lines written on the Rocky Mountains. *In* Griswold, R. W. Poets and poetry of America, p. 357.

Love. [Signed A. P.] *In* American Monthly Magazine, v. 2, no. 4, July, 1830, p. 266.

Sixty-eight lines. First line: "There came a train, on a pleasant eve." Not in any of his collected poems.

Love. *In* Boston Pearl, v. 5, no. 20, Jan. 30, 1836, p. 155.

Love rules. *In* Bromwell, J. H. Gems from the quarry, v. 2, p. 21.

Four stanzas of 5 lines each. First line: "Evermore the people listen." Not in any of his collected poems.
Same in Voice of Masonry, v. 29, no. 2, Feb., 1891, p. 90.

The magnolia. *In* Library of Southern literature, v. 9, p. 4054.

Ma Trieste Cherie. V.... [By Albert Pike.]. [Washington?] Feb. 26, 1869. [2]p. 8°.

The Mason's Holy House. *See* A Holy House to build.

Metrical (A) description of a fancy ball given at Washington, 9th April, 1858. Dedicated to Mrs. Senator Gwin. Franklin Philp, Washington, 1858. 40p. 4°.

Ascribed to Albert Pike.

Midnight, a lament. *In* Boston Pearl, v. 5, no. 25, Mar. 5, 1836, p. 196.

Morning, a lament. *In* Boston Pearl, v. 5, no. 24, Feb. 27, 1836, p. 190.

Musings. *In* Boston Pearl, v. 4, no. 35, May 9, 1835, p. 281.

73 lines. First line: "We sit and watch the current of our life." Not in any of his collected poems.

Night Musings. *In* Boston pearl, v. 4, no. 9, Nov. 8, 1834, p. 73.

143 lines. First line: "Ay, 'tis a glorious night." Not in any of his collected poems.

Ode. *In* Library of Southern literature, v. 9, p. 4058. New Age, v. 24, no. 6, June, 1916, p. 246.

First line: "When shall the nations all be free"

Ode. *In* American Quarterly Review of Freemasonry, v. 2, Oct., 1858, p. 161.

Two stanzas of 9 lines each. Used in the 19°, A. A. S. R.

Ode to the mocking bird. *In* The Essayist, v. 1, no. 7, July, 1832, p. 209.

Odes sung in the Sublime Order of Good Samaritans. *In his* Official Bulletins, v. 3, p. 684-686.

"In part written, in part selected, and changed for Ill:. Bro:. Robert Macoy by Bro:. Albert Pike."

The old canoe. *In* Masonic Age, v. 3, no. 1, Jan., 1881, p. 12. Masonic Journal, v. 2, no. 3, Feb. 1, 1877, p. 34. Masonic Review, v. 65, no. 2, Mar., 1886, p. 89. National Freemason, v. 9, no. 13, Sep. 28, 1867, p. 199. *His* Official Bulletins, v. 9, p. 371.

In this latter reference, Pike says: "Long before the war, the appended simple but charming verses appeared, it is said, without any signature or address, in the 'Arkansas Gazette,' at Little Rock. Their authorship continues to be ascribed to Albert Pike, although he has again and again in print disclaimed it. He is not their author."

Ora atque labora. (Pray and work.) [and] Autumn. [By Albert Pike.] [Washington? about 187—.] [3]p. 8°.

First poem was originally written in 1844; the second one in 1842.
Same in Light, (Topeka, Kan.) v. 1, no. 11, Oct., 1885, p. 86. The Knickerbocker, v. 26, no. 2, Aug., 1845, p. 138. Official Bulletins, v. 7, p. 401-402. Library of Southern Literature, v. 9, p. 4055-4056. Voice of Masonry, v. 26, no. 1, Jan., 1888, p. 64.

Our afternoon of life. *In* Masonic Journal, v. 2, no. 10, Sep., 1889, p. 294. Voice of Masonry, v. 28, no. 4, April, 1890, p. 317.

One stanza of 8 lines. First line: "Our afternoon of life has come."

Poem, read before the National Convention of Mexican War Veterans. [By Albert Pike.] January 16,, 1874. [Washington?] [1874.] [3]p. 8°.

[Poem.] *In* Masonic Guide, v. 5, no. 3, Aug., 1894, p. 118. Masonic Review, v. 83, no. 5, June, 1895, p. 296. Square and Compass, v. 3, no. 3, May, 1894, p. 57.

Two stanzas of 13 lines each. First line: "The sky is blue, the stars are bright." Not in any of his collected poems.

Poets—past and present. *In* Boston (The) Book, 1837. Edited by B. B. Thacher, p. 40-42.

Six stanzas of 6 lines each. Not in any of his collected poems.

The progress of poetry. *In* American Monthly Magazine, v. 1, No. 9, December, 1829, p. 644-646 and v. 2, no. 9, Dec., 1830, p. 603-604.

Signed: A. P. 17 stanzas of 10 lines each. First line: "There shone a light on the eastern world." Not in any of his collected poems.

Reunion. [By Albert Pike.] Written to be sung at Charles W. Boteler's, on Thursday evening, January 21, 1869. [Washington.] Cunningham & M'Intosh, printers, [1869] [1]p. folio broadside.

Seventeen stanzas of 7 lines each. Not in any of his collected poems in this form.

Re-Union. [By Albert Pike.] Washington, January, 1869. [2]p. 8°.

Eight stanzas of 4 lines each. Same as certain of the stanzas in the preceding poem, with personal names and allusions omitted, as well as all the refrains in the former poem. *Same in his* Official Bulletins, v. 6, p. 413.

Robin, The. *In* The Essayist, v. 1, no. 12, Sep., 1833, p. 373.

Editor says: "From a collection of poems soon to be published." He refers to Pike's "Prose sketches and poems written in the Western country." Bost. 1834.

Seventy years. *In* Voice of Masonry, v. 18, no. 8, Aug., 1880, p. 603.

Eight stanzas of 6 lines each. First line: "Seventy years to the very day." Not in any of his collected poems.

Shelley. *In* Library of Southern literature, v. 9, p. 4059.

Song. *In* Boston Pearl, v. 5, Feb. 6, 1836, p. 163.

Published in his poems as "The husband to his wife."

Song. [By Albert Pike.] [Washington?] N. d. [1]p. 8°.

Seven stanzas, with refrain to each stanza. First line: "Here's a health to the Prince of brave men and good fellows." Not in any of his collected poems.

Song. *In* Boston Pearl, v. 5, no. 5, Oct. 17, 1835, p. 35.

First line: Let the dreaming astronomer number each star.

Song. *In* Boston Pearl, v. 4, no. 2, Aug. 27, 1834, p. 19.

Two stanzas of 8 lines each. First line: "No, Mary, believe not I ever can change." Not in any of his collected poems.

Song. *In* American Monthly Magazine, v. 1, new series, Feb., 1836, p. 146.

Two stanzas of 8 lines each. First line: "O'er the dark sea of life as man wanders in sorrow." Not in any of his collected poems.

Song. *In* Hartford Pearl, v. 4, no. 1, Aug. 20, 1834, p. 7.

Three stanzas of 8 lines each. First line: "Oh, think not dear girl when the shadows of care." Not in any of his collected poems.

Song. *In* American Monthly Magazine, v. 1, new series, Jan, 1836, p. 37.

Eight stanzas of 4 lines each. First line: "There is a wee and pretty maid." Not in any of his collected poems.

Song. [By Albert Pike.] [Washington.] N. d. [1]p. 8°.

Same in his Official Bulletins, v. 7, p. 403.
First line: "When Autumn's chilly winds complain."

Song [and]. The Light of days long past. [By Albert Pike.] [Washington?] N. d. [2]p. 8°.

First line of first poem:" When Autumn's chill winds complain."

Song. *In* Hartford Pearl, v. 4, no. 3, Sep. 3, 1834, p. 25.

Four stanzas of 6 lines each. First line: "Woman! woman!" Not in any of his collected poems.

Song. ''Oh, Jamie brewed a bowl o' punch.'' [By Albert Pike.] [Washington? about 1860.] [2]p. 8°.

Song. *In* The Life-wake of the fine Arkansas gentleman. [Pike] p. 25-31.

First line: "A gentleman from Arkansaw, not long ago, 'tis said." Generally known as his "Spree at Johnny Coyle's."

Sonnet. *In his* Official Bulletins, v. 7, p. 423.

Sonnet to the rain. *In* Boston Pearl, v. 4, no. 29, Mar. 28, 1835, p. 233.

Fourteen lines. First line: "Sweet rain! tthe concentrated breath of heaven." Not in any of his collected poems.

The Southern island. *In* The Ladies' Companion, v. 13, May, 1840, p. 45.

Six stanzas of 8 lines each. First line: "There is an isle circled by Southern seas." Not in any of his collected poems.

Southrons hear your country call you. *See* Dixie.

This is the first line of his "Dixie."

Summer. *In* American Monthly Magazine, v. 2, no. 5, Aug., 1830, p. 341.

Signed: A. P. 72 lines. First line: "The summer is fair in the sun-lit air." Not in any of his collected poems.

Sunset. *In* Boston Pearl, v. 4, no. 41, June 20, 1835, p. 330. *In his* Official Bulletins, v. 7, p. 422-423.

Published in his collected poems as "Sunset in Arkansas."

Time's oration. *In* The Ladies' Companion, v. 12, Apr., 1840, p. 265.

Fourteen stanzas of 8 lines each. First line: "Oh! I am but a poor and simple wight." Not in any of his collected poems.

"To a friend he could never say no." (Sung at Cornelius Wendell's, February 11, 1869.) [Washington.] Cunningham & M'Intosh, printers [1869] [1]p. 8°.

Nine stanzas of four lines each. First line: "I have travelled the prairies all over." Not in any of his collected poems.

To Ambition. *In* Hartford Pearl, v. 4, no. 10, Nov. 15, 1834, p. 81. Not in any of his collected poems.

To Apollo. *In* American Monthly Magazine, v. 2, no. 5, Aug., 130, p. 311. Library of Southern Literature, v. 9, p. 4060.

Published afterwards as part of his "Hymns to the gods."

To Ceres. *In* Duyckinck. Cyclopedia of American Literature, v. 2, p. 520. The Essayist, v. 1, no. 4, April, 1832, p 106. Linton, W. J. Poetry of America, p. 115.

Published afterwards as part of his "Hymns to the gods."

To E. P. *In* The Essayist, v. 1, no. 12, Sept. 1833, p. 363.

Signed: A. P. 20 lines. First line: "How sinks the sad and lonely heart." Not in any of his collected poems.

To J. M. T. *In* The Essayist, v. 1, no. 11, Mar., 1833, p. 338.

Signed: Arkansas, December, 1832, A. P. 2 stanzas of 8 lines each. First line: "Though my faults and my follies have broken the ties." Not in any of his collected poems.

To my wife. *In* The Knickerbocker, v. 26, no. 3, Sept., 1845, p. 202.

Five stanzas of 10 lines each. First line: "Our shallop long with tempest tried." Not in any of his collected poems.

To Neptune. *In* American Monthly Magazine, v. 2, no. 5, Aug., 1830, p. 298.

Signed: A. P. Revised and published later as part of his "Hymns to the gods."

To Poseidon. *In* Library of Southern Literature, v. 9, p. 4044.

Part of his "Hymns to the gods."

To a robin. *In* Library of Southern Literature, v. 9, p. 4052.

To Somnus. *In* The Essayist, v. 1, no. 6, June, 1832, p. 172.

Signed: A. P. Published afterwards as part of his "Hymns to the gods."

To Spring. *In* Griswold, R. W. Poets and poetry of America, p. 357. Harper's Family Library, no. CXI, p. 298. Linton, W. J. Poetry of America, p. 117. Masonic Mirror and Keystone, v. 8, no 18, May 4, 1859, p. 205. New Age Magazine, v. 16, no. 5, May, 1912, p. 485. The Pearl and Literary Gazette, v. 3, no. 17, Mar. 29, 1834, p. 139. Pray, Isaac C. Prose and verse, p. 35.

To the first coming flowers of Spring. *In* American Monthly Magazine, new series, v. 1, Jan., 1836, p. 30.

Revised and later published as "The first wild flowers of Spring."

To the mocking bird. *In* Blackwoods Magazine, v. 47, no. 293, Mar., 1840, p. 354. Griswold, R. W. Poets and poetry of America, p. 356. James, J. G. Southern students' handbook of selections for reading and oratory, p. 205-207. Library of Southern Literature, v. 9, p. 4046. Pike, Albert. Official Bulletins, v. 7, p. 516-517. Stedman & Hutchinson. Library of American Literature, v. 6, p. 486-487.

To the South wind. *In* American Monthly Magazine, v. 2, no. 1, April, 1830, p. 39.

Signed: A. P. 6 stanzas of 10 lines each. First line: "Fair wind that comest from over the sea." Not in any of his collected poems.

To Venus. *In* American Monthly Magazine, v. 2, no. 6, Sept., 1830, p. 376.

Signed: A. P. Published later as part of his "Hymns to the gods."

Truth. *In* Bromwell, J. H. Gems from the quarry, v. 2, p. 277.

Same as his "All wait", which see. Not in any of his collected poems.

An unpublished poem of Albert Pike. *In* New Age Magazine, v. 6, no. 3, Mar., 1907, p. 290.

Three stanzas of 16 lines each. First line: "Who shall judge a man from nature." Not in any of his collected poems. Same as "God counts by souls."

Voice (The) of the age. *In* Masonic Mirror and Keystone, v. 3, no. 8, Feb. 22, 1854, p. 57.

Five stanzas of 6 lines each. Not in any of his collected poems.

The waif returned. [By Albert Pike.] [Washington?] August 16, 1875 [1]p. 8°.

Same in his Official Bulletins, v. 8, p. 330.

The widow mother watching her first born. *In* Boston Pearl, v. 4,no. 44, July 11, 1835, p. 353.

101 lines. First line: "It was a silent midnight of young June." Not in any of his collected poems.

The widowed heart. *In* Foote, H. S. Bench and bar of the South and Southwest, p. 189-191. Library of Southern literature, v. 9, p. 4050-4052. Stedman & Hutchinson. Library of American literature, v. 6, p. 487-489.

"Wilt thou on thy sweet bosom wear?" [By Albert Pike.] [Washington?] November 13, 1874. [1]p. 8°.

Same in his Official Bulletins, v. 8, p. 330.

Words of sympathy. For . . . and his dead child's mother.. *In his* Official Bulletins, v. 6, p. 450-451.

Three stanzas of 7 lines each. First line: "The young leaf lives in spring its little hour." Not in any of his collected poems.

Yes, call us rebels. *In* Brock, Sallie A. The Southern amaranth, p. 294-295.

Same in Mason, Emily V. Southern poems of the war. Moore, Frank. The Rebellion Record, v. 1, p. 66 (appx.).

Five stanzas of 8 lines each. First line: "Yes, call us rebels! 'tis the name." Not in any of his collected poems.

MISCELLANEOUS.

An address delivered by Albert Pike, esq., to the young ladies of the Tulip Female Seminary, and cadets of the Arkansas Military Institute, at Tulip, on 4th June, 1852. Little Rock, Wm. E. Woodruff, printer, 1852. 31p. 8°.

Commentaries on the Kabbala. *See* Manuscripts.

Crayon sketches and journeyings, Nos. 1-3. *In* Boston Pearl, v. 4, nos. 9, 11, 18, Nov. 8 and 22, 1834 and Jan. 10, 1835, p. 69, 88, 143.

Cursory thoughts. *In* Brownell, J. H. Gems from the quarry, v. 2, p. 381.

Dreams. *In* American Monthly Magazine, v. 2, no. 5, p. 298.

Signed "A" and directly following it is a poem ("Ambition") signed "P," that is Albert Pike.

Emigravit. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 354.

Great thoughts selected or written by Albert Pike. *In* Voice of Masonry, v. 28, no. 2, Feb., 1890, p. 83-88.

Irano-Aryan theosophy and doctrine as contained in the Zendavesta. *See* Manuscripts.

A journey to Xemes. *In* Boston Pearl, v. 5, no. 23, Feb. 20, 1836, p. 180.

Lectures of the Arya. *See* Manuscripts.

Letters from Arkansas, no. 1. *In* New England Magazine, v. 9, Oct., 1835, p. 263.

Letters from Arkansas [no. 2]. *In* American Monthly Magazine, Jan., 1836, p. 25.

Life in Arkansas. *In* American Monthly Magazine, v. 1, new series, Feb. and Mar., 1836, p. 154, 295.

Life's journey. *In* Square and Compass, v. 14, no. 5, July, 1905, p. 121-122.

The loneliness of old age. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 390.

Mexico. Anniversary of the capture of the capital. The veterans celebrate the event. Grand excursion to Marshall Hall. Interesting literary exercises. An oration by General Albert Pike. . . . Reprinted from the Washington Chronicle, Sept. 15, [1875]. 8p. 8°.

Oration by Pike, p. 2-7.

Moral influences. *In* Brewer D. J. and others. World's best orations, v. 10, p. 3945.

Narrative of a journey in the prairie. *In* Arkansas Historical Association Publications, v. 4, p. 66-139.

Originally published in his "Prose sketches and poems written in the Western country" and afterwards running as a serial in the Arkansas Advocate, in 1835.

Old age and death. *In* James, J. G. Southern students handbook of selections for reading and oratory.

The philosophy of bowling. *In* American Monthly Magazine, v. 2, no. 10, Jan., 1831, p. 687; The Boston Pearl, v. 4, no. 13, Dec. 6, 1834, p. 103.

The philosophy of a cigar. *In* American Monthly Magazine, v. 2, no. 4, July, 1830, p. 254.

Signed: Newburyport, "P."

The philosophy of walking. *In* American Monthly Magazine, v. 2, no. 5, Aug., 1830, p. 313; Boston Pearl, v. 4, no. 13, Dec. 6, 1834, p. 104.

Prose sketches and poems, written in the Western country. *See* Poetry.

Real atheim hopeless, soulless, godless. *In* Square and Compass, v. 15, no. XI, Jan., 1907, p. 288-291.

True greatness prefected by unmerited misfortune. *In* James, J. G. Southern students handbook of selections for reading and oratory.

The walking gentleman. *In* The Knickerbocker, v. 25, no. 3, March, 1845, p. 209, and v. 27, nos. 2, 3, 5, Feb., Mar., May, 1846, p. 140, 230, 398.

Thoughts on various subjects. Not signed, but the index to the magazine gives Pike as the author.

Western superstitions. *In* Boston Pearl, v. 5, Sept. 26, 1835, p. 14.

Western Traveling. *In* Boston Pearl, v. 4, no. 6, Sept. 24, 1834, p. 48.

MANUSCRIPTS

MANUSCRIPTS—General

These manuscripts are in Albert Pike's own fine hand, written with a quill pen, which he whittled into shape himself, as he used no other kind. With but few exceptions, they are all in the Library of the Supreme Council of the 33rd Degree, at Washington.

[Ancient alphabets.] 65p. Oblong 8°.

Each page ruled with a border of red. Bound in full morocco.

Ancient faith and worship of the Aryans, as embodied in the Vedic hymns. [By Albert Pike.] 1872-3. 2v. and supp. [v. 3] 2162p. Roy. 8°.

V. 1, 26+698 p. V. 2, 12+p. 699-1384. [V. 3] 10+742 p. Ornamental title pages to each volume, varying slightly in design and coloring. Several illustrations in v. 1 and 2 the title pages and illustrations being done in pen and ink by E. B. MacGrotty, 33°, Hon∴ of Washington. The pages of all the volumes are ruled with a border in colored inks, paged in black, with many underscores of words in colored inks, all by the same pen artist. Bound in full purple morocco, panelled backs. Paper of fine heavy quality, with gilt edges.

[Autobigraphy. By Albert Pike.] 86 typewritten pages on legal size paper.

From stenographic notes dictated by Pike, April 26, 1886, when he was in a reminiscent mood. Not the same as his printed "Autobiography," and much more extensive.

Commentaries on the Kabbala. [By] Albert Pike. Louisville Ky., 1878. 235 written pages. Roy. 8°.

The title page is handsomely done in india ink with an artistic border, also in india ink and the MS. pages are all mounted on extra sheets. Bound in full morocco. Gilt edges; not paged.

Essays. By Albert Pike. Washington, D. C., about 1880. 2166p. Roy. 8°

Written on fine ruled paper, all pages bordered in colored inks, pages not numbered. Dedicated to Vinnie Ream Hoxie, the famous sculptress. No title pages. All volumes bound uniformly in full blue morocco, gilt edges. Lettered on back: "Essays. Pike," with the volume number and number of essays in each volume, each volume lettered on front cover: "Vinnie. Pegni d'affetto."

V. 1. 469 p. Contents: Dedication, introduction, essays, 1-6. No. 1, Of content in life; 2, Of honoring the dead; 3, Of self-education; 4, Of men's opinions of women; 5, Of wrecks and waifs of poetry; 6, Of self-investing.

V. 2. 476 p. Essays 7-12. No. 7, Of habits and their slaves; 8, Of the death of love; 9, Of symbols decaying into idols; 10, Of indian nature and wrong; 11, Of my books and studies; 12, Of law and lawyers.

V. 3. 441 p. Essays 13-18. No. 13, Of rowing against the stream; 14, Of shattered idols; 15, Of coin and currency; 16,, Of greatness; 17, Of poverty and its compensations; 18, Of the policy of forgiveness.

V. 4. 464 p. Essays 19-23. No. 19, Of some old dramatists; 20, Of pay and reward for public service; 21, Of forces; 22, Of values; 23, Of the ability to say "NO."

V. 5. 316 p. Essays 24-29. No. 24, Of pleasant and sad remembrances; 25, Of sympathy; 26, Of chance and school-teaching; 27, Of godlessness and retribution; 28, Of leaves and their falling; 29, Jubilee of scoundrelism.

Excerpts. 176 written pages. Roy. 8°.

Selections in poetry and prose from famous writers, in various languages, epitaphs, etc. etc. One side of each page blank. Pages throughout ruled with a border of various colored inks, while many words are likewise underscored. Bound in ½ morocco, and lettered on back "Excerpts." Not paged.

Extracts from and comments upon the Kabbala. Translated by Albert Pike. 1860. 383 written pages. Wide 8°.

All pages ruled with a border of red. Bound in full morocco. Not paged.

Irano-Aryan theosophy and doctrine as contained in the Zend Avesta. [By] Albert Pike. 1874. 3v. 2344p. Roy. 8°.

V. 1, 32 + 757 p. insert of 4 p. at p. 634; v. 2, 8+p. 758-1514; v. 3, 10+ p. 1515-2198+92 p. Ornamental title pages to each volume, varying somewhat in design and coloring, copy of a picture from Landseer's Sabaean Researches, and a map of "Imperium Persicum" in v. 1, and several illustrations in v. 3, the title page, illustrations and map, all being done in india ink by E. B. MacGrotty, 33°, Hon., of Washington, while the pages of all the volumes are ruled with a border in colored inks, paged in black, with many underscores of words in colored inks, all by the same pen artist. Bound in full purple morocco, with panelled backs. Paper of fine heavy quality, with gilt edges.

Lectures of the Arya. [By Albert Pike.] [About 1873.] 8v. 1499 p. Wide 8°.

V. 1. Lecture I. The Aryan race. Its emigration and last division. The country, character and manners of the Indo and Irano Aryans. 151 p.
V. 2. Lecture II. The Veda. The Aryan language. 166 p.
V. 3. Lecture III. The deities of the Veda, Agni-Indra. 152 p.
V. 4. Lecture IV. Vishnu, Vayu, Tvashtri, Rudra, Varuna, Mitra, Aryaman, the Acvins, Ushas, Pushan, and other deities. 163 p.
V. 5. Lecturc V. The Vedic deities. Rudra: The Angirasas; the Acvinau: Soma, the Ribhus: Parjanya: Vata: Sarama: Sarasvati: the Apsarsas: Sinivali: Raka: Purusha: Prajapati: Hiranyagarbha. 177 p.
V. 6. Lecture VI. The Zenda-Avesta. The Gathas. The doctrine of Zarathustra. 159 p.
V. 7. Lecture VII. Ahura Mazda and the Amesha Cpentas. 165 p.
V. 8. Lecture VIII. The last four gathas and Legendary. 288 p. "Aryan notions of Philo Judaeus." 78 p.
Title page to each volume and much underscoring throughout, all probably done by E. B. MacGrotty, 33°. Hon., of Washington. Most of the sheets written on one side only. Bound in ½ blue morocco.

[Letters and documents, personal and official. By Albert Pike. From 1838-1891 and 1 volume of undated letters and notes. Collected and arranged by Wm. L. Boyden, 33° Hon. of Washington.] 15v. 4,000p.

Mounted on folio size manila sheets and bound in buckram. V. 1-14, dated letters and documents; v. 15, undated.

Maxims of military science and art. From the writings of Napoleon, Napier, Jomini, McDougall, Graham, Mitchell, Suchet, Bisset, Alison, and others, with occasional illustrations and applications. Compiled by Albert Pike. 1863. 6v. 2,182 written pages. Wide 8°.

In heavy cardboard covers, not bound.

Maxims of the Roman law and some of the ancient French law. As expounded and applied in doctrine and jurisprudence. Compiled by Albert Pike. [1876.] 13v. 3,340p. 8°.

In heavy cardboard covers, not bound. Preface states that he had been engaged on this work for many years. Not paged.

Muster roll of Capt. Albert Pike's company in the regiment of Arkansas volunteers . . . from the 31st day of August, 1846 . . . to the 31st day of October, 1846. 2p. folio.

Dated Monclava, Mexico, October 31, 1846. In the archives of the War Department at Washington.

Muster roll of Capt. Albert Pike's company in the Arkansas regiment of mounted volunteers . . . from the 31st day of October, 1846 . . . to the 31st day of December, 1846. 2p. folio.

Dated Hacienda de Patos, Mexico, December 31, 1846.
In the archives of the War Department at Washington.

Notes on the civil code of Louisiana. Made by Albert Pike in 1855, at New Orleans. 218 written pages 8°.

Title page and text throughout ruled with a border of red ink. Bound in ½ morocco.

The past teaching the present and the future. [By Albert Pike.] [About 1867.] 122p. 8°.

In heavy cardboard cover, unbound. The unpublished portions of his articles under that title which he wrote and published in the Memphis Appeal, Memphis, Tennessee while editor of that paper, shortly after the Civil War. Mounted on sheets in the same volume are the clippings of the published portions of the work. Political.

Rules and orders of the Supreme Court of the United States. [N. p. about 1834?]

This printed copy of the Rules is interleaved with blank pages and additional blank pages at back, and paged in Pike's own hand, and contains 29 pages of MS. notes and amendments, by Pike.

To the mocking bird. [Signed] Albert Pike, December, 1834. [4] p. Roy. 8°.

This poem is in 6 stanzas of 11 lines each. It is the earliest known specimen of Pike's handwriting.

Translations of the Rig-Veda. The Maruts. [By] Albert Pike. [187—.] 4v. 2,641p. Roy. 8°.

V. 1. Hymns I. 6 to I. 100. p. 1-699.
V. 2. Hymns VI. 66 to X. 103. p. 700-1457.
V. 3. Hymns V. 52 to V. 87. p. 1-569.
V. 4. Hymns I. 142 to III. 54. p. 570-1184.
Ornamental title pages to each volume, varying slightly in design and coloring. All pages ruled with borders in colored inks. Title pages and rulings done by E. B. MacGrotty, 33°, Hon∴ of Washington. Bound in ½ red morocco. Paper of fine and heavy quality, mottled or marbled edges.

Translations from the Rig-Veda. Friends of Indra: Svadha: The Purusha Sukta: Savitri: Names of Rishis. [By] Albert Pike. [187—.] 562p. Roy. 8°.

Ornamental title page. All pages ruled with borders in different colors by E. B. MacGrotty, 33°, Hon∴ of Washington who also designed the title page. Bound in ½ red morocco. Paper of fine and heavy quality, mottled or marbled edges.

Translations of the Rig-Veda. Hymns to Tvashtri and the Ribhus. [By] Albert Pike. [187—.] 716p. Roy. 8°.

Ornamental title page and all pages ruled with a border of colored inks, by E. B. MacGrotty, 33°, Hon∴ of Washington. Paper of fine and heavy quality, marbled edges.

Translations of the Rig-Veda. Of the Devas generally and of passages which mention the Arya and Dasyu. [By Albert Pike.] [187—.] 632p. Roy. 8°.

Ornamental title page and all pages ruled with a border of different colors, by E. B. MacGrotty, 33°, Hon∴ of Washington. Bound in ½ red morocco. Paper of fine and heavy quality, marbled edges.

Translations of the Rig-Veda. Consecutive. [By Albert Pike.] [1872-1886?] 7v. and 3 supp. v. 6,939p. Roy. 8°.

V. 1. Aryan light religions. Summary. Introductory chariots. Hymns I. 1 to I. 30. 786 p.
V. 1A. I. 1 to I. 30. Supplements. Agni: Apammapat: Vishnu: Vayu: The wives of the Vedas: Hiranya-Garbha and Praja-pati. 735 p.
V. 1B. Supplementary to Hymn I. 30. Varuna, Mitra and Aryaman. 492 p.
V. IC. I. 1 to I. 30. Supplements. Dyava—Prithivi: Cyena: Ghrita: Hari: Yama: Cura and Sina: Vanaspati. 540 p.
V. 2. Supplements to I-30 continued. Vasishtha...........Foes of Indra. Hymns 31 to 33. Supplement to I-32 and 33. Indra. Hymns I-34, 35. 644 p.
V. 3. Hymns I-36 to I-52, inclusive. Supplement to I-40. Agni as Brahmanas-Pati and Brihas-Pati. 684 p.
V. 4. Hymns 53 to 77, inclusive. 659 p.
V. 5. Hymns 78 to 102, inclusive. 674 p.
V. 6. Hymns 103 to 120, inclusive. 724 p.
V. 7. [Hymns] I, 121 to I, 141, with I, 164, 1001 p.
Ornamental title pages, varying somewhat in style and coloring and all pages ruled with borders of various colored inks, the work of E. B. MacGrotty, 33°, Hon∴ of Washington. Bound in ½ red morocco. Paper of fine and heavy quality, marbled edges. A preface to vol. 7 states that he was engaged for more than fourteen years in the study of the Rig Veda and the compilation of works on this subject.

[Vocabularies of indian languages. By Albert Pike.]. 119 written pages, with two inserts of 28 and 6 pages respectively. Folio.

An autograph letter inserted begins: "These vocabularies were collected by me in 1857 and 1861, with great care and particularity and are correct."

[Vocabularies of Sanscrit words. By Albert Pike.] 79 written pages on legal size writing paper.

In 7 parts, each part covered in brown paper and fastened with clips. Evidently made for his own use in translating the Rig Veda and other oriental writings.

MANUSCRIPTS—Masonic

[Account as Grand Commander of the Supreme Council, 33°, Southern Jurisdiction, Ancient and Accepted Scottish Rite of Freemasonry, from 1861 to 1878.]

Written in a Cash Book of 288 p. Some pages blank. Loosely inserted are 44 p. of accounts.

An address on the actions and character of John Anthony Quitman, Sovereign Grand Inspector General. [By Albert Pike.] 1860. 45 written pages. Wide 8°.

Each written page bordered in red ink. This is the MS. from which printed copies were made, appearing in the proceedings of the Supreme Council, for 1860, and also in separate pamphlet form. Not paged.

Address of the M. P. Sovereign Grand Commander [Albert Pike] to the Supreme Council for the Southern Jurisdiction of the United States, at its adjourned session, on the 5th day of the Heb∴ M∴ A. M. 5620 [1860.] 86 written pages. Wide 8°.

Other side of each sheet blank, both sides bordered in red. Not paged. The MS. from which the address in the Transactions of the Supreme Council for 1860 was printed. Bound with his address on John Anthony Quitman.

[Book of the words. By Albert Pike.] [N. d.] 350 written pages. Oblong 8°.

Fifteen illustrations. No lettering or title page, all pages ruled with a border of red. Paper of fine and heavy quality. Bound in full blue morocco. This is his MS. of his "Book of the words."

Ceremony of adoption of the child of a brother by a symbolic Iodge. Prepared by the Bro∴ A[lbert] P[ike]33°, 1858. [Followed by another title page:] Ceremony of adoption of the child of a brother by a Lodge of Perfection. Prepared by the Bro∴ A[lbert] P[ike] 33°, 1858. 100 pages. Wide 8°.

All pages ruled with a border of red. Bound with his "Funeral Ceremony of a Knight Rose Croix."

Ceremony of baptism of the child of a brother by a Lodge of Perfection. Prepared by the Bro∴ A[lbert] P[ike] 33°. [1870?] 76p. wide 8°.

All pages bordered in red. Bound with his "Funeral Ceremony of a Knight Rose Croix."

Ceremony of inauguration and installation of a Lodge of Perfection. [By Albert Pike.] [1870?] 51p. Wide 8°.

All pages ruled with a border of red. Other "Ceremonies" are bound with this MS. and the volume lettered "Inaugurations and Installations." The other MSS. are noted in their proper places, with a reference to the first item in the volume.

[Ceremony of] Inauguration of a Council of Princes of Jerusalem. [By Albert Pike.] [1870?] 59p. Wide 8°.

All pages ruled with a border of red. Bound with his "Ceremony of inauguration and installation of a Lodge of Perfection."

Ceremony of inauguration of a Chapter of Rose Croix. [By Albert Pike.] [1870?] 52p. Wide 8.

All pages ruled with a border of red. Bound with his "Ceremony of inauguration and installation of a Lodge of Perfection."

Ceremony of inauguration of a Council of Kadosh, 30th degree. [By Albert Pike.] [1879?] 35p. Wide 8°.

All pages ruled with a border of red. Bound with his "Ceremony of inauguration and installation of a Lodge of Perfection."

[Ceremony of] Inauguration and installation of a Grand Consistory of Princes of the Royal Secret. [By Albert Pike.] [1870?] 66p. Wide 8°.

All pages ruled with a border of red. Bound with his "Ceremony of inauguration and installation of a Lodge of Perfection."

Ceremony of reception of a Louveteau by a symbolic lodge. Prepared by the Bro∴ A[lbert] P[ike] 33°. 1858. 115p. Wide 8°.

All pages ruled with a border of red. Bound with his "Funeral ceremony of a Knight Rose Croix."

The Degree of Master Mark Mason. Being the work of the Gr[and] Council of Princes of Jerusalem of South Carolina, and the oldest work extant anywhere. From a MS. in the archives of the Supreme Council at Charleston. 34p. Wide 8°.

On the other side of the title page "Copied by me this 8th day of May, 1858. Albert Pike, Sov∴ Gr∴ Insp∴ Gen∴ 33d degree." All pages ruled with a border of red. Not paged. Bound in full morocco, gilt edges. Other MSS. are bound with this item, the volume lettered on back "Rituals, Various." The other items are noted in their proper place, with a reference to this first MS.

Excerpta Latomica. [Compiled by Albert Pike.] [About 1870.] 294 written p. Wide 8°.

All pages ruled with a border of red, with occasional pen illustrations. Full bound in morocco. Gilt edges.
Extracts from writers on masonry and philosophical subjects connected therewith, of various authors, with occasional remarks by Pike.

Funeral ceremony of a Knight Rose Croix. [By Albert Pike.] [187—.] 37p. Wide 8°.

All pages ruled with a border of red. Bound in with this MS. are others by Pike, the volume being lettered: "Funeral Ceremony, Ceremony of baptism, Reception of Louveteau, Ceremony of adoption."

Grand Maitre Ecossais, or Scottish Elder Master and Knight of St. Andrew, being the fourth degree of Ramsay, or of La Regime Reformé in Rectifié of Dresden. From an old manuscript in English, without name or date, found by me in the archives of the Supreme Council at Charleston. 36 written p. Wide 8°.

On other side of title page: "Correctly copied by me, May 7th, 1858, in substance. Albert Pike, Sov∴ Gr∴ Insp∴ Gen∴ 33d." All pages ruled with a border of red. Not paged. Bound with his "Degree of Master Mark Mason."

Knight of the Mediterranean Pass. From an old manuscript in the archives of the Supreme Council at Charleston, South Carolina. 21 written p. Wide 8°.

On other side of title page: "Accurately copied by me this 4th day of May, A. D. 1858. Albert Pike, Sov∴ Gr∴ Insp∴ Gen∴ 33d." All pages ruled with a border of red. Bound with his "Degree of Master Mark Mason."

Lycée du second grade ou Aspirante gens d'Armes des A[mis] de la N[ature] et des A[rts] du Nord et de Charleston. Le 2me D∴ 10eme mois de la fondation 40,002. et de la 7e de la R-g-n-t-n. 1802. Commencé la 8eme année. 28 written p. Wide 8°.

On the other side of title page: "Translated by me May 4, 1858, from an old French MS. found by me in the archives of the Supreme Council at Charleston. Albert Pike. Sov∴ Gr∴ Insp∴ Gen∴ 33d." On the following page is the translation of the title: "Lyceum of the second degree, or Aspirant soldiery of the friends of nature and the arts of the North of Charleston. The second day of the 10th month of the year of the foundation 40,002 and of that of Regeneration, 1802. Commenced the 8th year."
All pages ruled with a border of red. Bound with his "Degree of Master Mark Mason."

[Masonic Philosophy. By Albert Pike.] [187—?] 444 written pages, 13 illustrations. Oblong 8°.

Symbolism, mythology, mysteries, etmology, etc., etc., particularly in its relation to the Ancient and Accepted Scottish Rite of Freemasonry.
Bound in full morocco, without title. All pages ruled with a border of red, with much underscoring of words in red. Paper of fine and heavy quality.

Masonic Rituals. In hoc signo vinces. Spes mea in deo est. [Translated by Albert Pike in 1854 and 1855. 889 written p. Royal 8°.

A beautiful example of the bookbinder's art. Bound in full morocco, tooled and inlaid with masonic emblems, front and back, edges of pages gilt, with masonic emblems tooled thereon. The book is lockable by means of two masonically designed locks, with key. Title page is handsomly lettered with many masonic devices thereon, by an artistic penman, probably E. B. BacGrotty, 33°, Hon∴ of Washington, and all the pages are ruled with a border of red. There are many blank pages in the volume in addition to the written pages.

Materials for the history of freemasonry in France and elsewhere on the continent of Europe, from 1718 to 1859. By Albert Pike, 33°. A∴M∴5636 [1876.] 6v. 1,460 written pages. Wide 8°.

In heavy cardboard covers, not bound. Pike says, in Transactions of the Supreme Council for 1874, p. 23 of the Appendix that these were prepared before the Civil War. Some portions of vol. 1 have been printed in his Official Bulletins and in the New Age Magazine, published by the Supreme Council, Southern Jurisdiction.

Register of Albert Pike, 33d∴ Sovereign Grand Inspector General for Arkansas, West Tennessee and the District of Columbia, commenced the 20th of March, A. D. 1853. 875p. Royal 8°.

The last entry is on page 611, October 1, 1864. Balance of pages blank. All pages ruled with a border of red. Some few pages here and there between pages 1 and 611, left blank. Bound in full brown morocco, gilt edges. Paper of fine quailty.

Rituals of Knight of the Red Cross, Knight Templar and Knight of Malta. 121p. 8°.

On heavy ruled paper; all pages bordered in red. "From a manuscript in possession of Ill∴ Bro∴ A. G. Mackey, of about the year 1805, as other entries in the manuscript show. Accurately copied by me with occasional corrections of the grammar only, this 12th day of May, A. D. 1858. Albert Pike, K. T. &c., Sov∴ Gd∴ Insp∴ Gen'l∴ 33rd." Bound in full leather, gilt edges. Lettered on front cover: "Rituals R∴ + ∴ K∴ T∴ and K∴ of M∴"

[Rituals of the Ancient and Accepted Scottish Rite of Freemasonry, from the first to the thirty-second degrees, inclusive. By Albert Pike.] 1866 398 written p. Wide 8°.

The title page has only the following on it: "Deus meumque jus." Then follows a cut or picture of the 33° eagle, after which: "Ordo ab chao." All cut from some printed source and pasted on this page.

The title page is ruled with a border of red, green and purple, balance of pages with a border of red. Bound in full morocco, gilt edges, with no lettering on cover.

Rituals. Rit Ancien et Accepté: Eighteenth degree. Rit Ancien et Accepté. Sovereign Prince Rose Croix. Also known as Sovereign Princes Freemasons of Heredom, or Knights of the Eagle and Pelican. From an ancient French manuscript, 1857.

On last page of MS: "Accurately translated by me from an old and very handsomely written MS. purchased in April, 1856, at the sale in Paris of the library of le F∴ Astier, this 28th October, 1857. Albert Pike. Sov∴ Insp∴ Gen∴ 33d."

Thirtieth degree. Rit Ancien et Accepté, or Scottish Masonry. Kadosch or Knight of the White and Black Eagle. Nec plus ultra. Dernier terme de l'Ecossisme. From an ancient French manuscript from the library of the Ill∴ Bro. F. Astier, Paris.

On last page of MS: "A true translation of the MS. in French, purchased for me at the sale of the Ill∴ Bro∴ F. Astier, in April, 1856. This translation being made and completed this 8th day of October, A. D. 1857. Given at Little Rock, Arkansas. Albert Pike, Rose Croix; K-H∴ S∴ P∴ R∴ S∴ 33d, Sov∴ Insp∴ Gen∴"

Chevalier Kadosch, or Knight f the Black Eagle: Grand Inspector, Grand Inquisitor, and Grand Elu.

On last page of MS: "Accurately translated by me October, 1857, from a French MS. purchased at the sale of the library of the deceased Bro∴ F. Astier, Paris, in 1856. Little Rock, Arkansas, Albert Pike, R∴ Croix∴ K-H∴ S∴P∴R∴S∴ & Sov∴ Insp∴ Gen∴ 33d."

The False Knight Kadosch, or Kadosch of Cromwell.

On last page: "Carefully translated by me from an old French MS. purchased for me at the sale of the library of the Ill:. Bro:. F. Astier, in Paris, In April, 1856. Albert Pike, Rose Croix:.S:.P:.R:.S:. Sov:. Gr:. Insp:.Gen:. 33d, 13th October, 1857."

Thirty-second degree of the Ancient and Accepted Scottish Rite. Sublime Prince of the Royal Secret. Truthful Guardian of the Sacred Treasurer. Translated from an ancient French manuscript from the library of the Ill:. Bro:. F. Astier, 1857.

On last page: "Accurately translated by me from an old French MS. purchased at the sale of the library of the Th:. Ill:. Bro:. Aster, at Paris, in April, 1856. Albert Pike, Rore Croix:. S:.P:.R:.S:. Sov:. Insp:. Gen:. 33d. Little Rock, Arkansas, 22d October, 1857."

192 p. Wide 8°. All pages ruled with a border of red. Occasional pen illustrations throughout. Not paged. Bound in full morocco, gilt edges. Lettered "Rituals, 18th, 30th,"

Ninth degree of Scottish Masonry and the Fourth of the Chapter of Rose Croix. Elect of the Nine, or Perfect Elect Mason. [Also:]

Tenth degree of Scottish Masonry and the Fifth of the Chapter of Rose Croix. Elect of the Fifteen. [Also:]

Eleventh degree of Scottish Masonry and the Sixth of the Chapter of Rose Croix. Sublime Elect or Elect of the Twelve Tribes.

105 written pages. Wide 8°. Before 1879. All pages ruled with a border of red. Not paged. Flexible morocco binding, lettered "IX, X, XI-De Castro."

Eighteenth degree. Ancient and Accepted Scottish Rite. Knight of the Eagle or Pelican, or Sovereign Prince Rose Croix. Revised by C[harles] L[affon] deL[adebat] and A[lbert] P[ike.] New Orleans, 1858. 188 written p. Wide 8°.

All pages ruled with a border of red. Bound in full morocco and lettered: "Ritual. 18th degree. C. L. deL. & A. P."

Thirtieth degree. Ancient and Accepted Scottish Rite. The Grand Elect Knight Kadosch:. or Knight of the White and Black Eagle. Revised by C[harles] L[affon] deL[adebat] and A[lbert] P[ike.] 1858. 139 written p. Wide 8°.

Each page ruled with a border of red. Bound in full morocco and lettered: "Ritual. 30th Degree. C. L. deL. & A. P."

Thirty-first degree. Ancient and Accepted Scottish Rite. Grand Inspector Inquiring Commander. Revised by C[harles] L[affon] deL[adebat] and A[lbert] P[ike.] 33ds. 1857. 40 written p. 8°. [Also:]

Thirty-second degree. Ancient and Accepted Scottish Rite. Sublime Prince of the Royal Secret:. Revised by C[harles] L[affon] deL[adebat] and A[lbert] P[ike.] 33ds. 1857. 137 written p. Wide 8°.

All pages of each MS. ruled with a border of red. Not paged. Bound in full brown morocco, gilt edges, and lettered: "Rituals. 31st & 32:. C. L. deL. & A. P."

Thirty-third degree. 153 written pages. Roy. 8°.

No lettering on cover, but pasted thereon is a slip in Pike's hand: "33. Ritual of 1868. Disused in 1880." All pages ruled with a border of red.

Subscription list of Official Bulletins. From vol. 1 to vol. 7. 29 written pages.

Written in a Cash Book of 281 p. Pasted on front cover is the above legend in Pike's own hand.

The symbolism of the blue degrees of freemasonry. Copied for the author [Albert Pike] by Edwin B. MacGretty, 33°, Washington, 1888. 400 p. Roy. 8°.

Bound in full blue morocco and lettered on back: "Esoterika. The symbolism of the blue degrees of freemasonry. Proprty of the Sup[reme] Co[uncil.] Washington, 1888." Of the 400 numbered pages, there are 133 blank pages.

The title page is a work of art, done in blue, black and gold, with a background of a large square and compass. Every word of the text is in imitation of print, none of the letters being joined, while every page is numbered in imitation of printed figures. All pages are of the finest quality of paper and ruled with a border of red.

MASONIC LITERATURE

ADDRESSES AND REPORTS.

Address. [By Albert Pike.] [N. p., about 1853.] 16 p. 8°. Caption title.

An address on the subject of St. Johns (Masonic) College, Batesville, Ark., and probably delivered there.

Addresses, by Albert Pike, delivered before the Western Star Lodge, No. 2, of Ancient Free and Accepted Masons, June 24, 1851, and at the laying of the corner-stone of the Masonic and Odd Fellows Hall, May 20, 1852, in the city of Little Rock. Little Rock, W. E. Woodruff, printer, 1852. 23 p. 8°. Cover title.

Same. Extracts. In Masonic Mirror and Keystone, v. 3, nos. 31, 32, Aug. 2-9, 1854, p. 244, 252.

Same. Extract: Freemasonry, its danger, and the remedy. (From an address before Western Star Lodge, No. 2, Little Rock.) *In* Southern and Western Masonic Miscellany, v. 4, no. 5, May, 1853, p. 143-148.

Addresses on the presentation of a sword of honor to M. E., Sir. Benj. B. French, Grand Master, on behalf of the Grand Encampment of Knights Templar of the United States, delivered before Washington Commandery of Knights Templar, No. 1, Wednesday, March 28, A. D. 1860, A. O. 742. Published by order of Washington Commandery, No. 1. Washington, Henry Polkinhorn, printer, 1860. 11 p. 8°.

The presentation speech by Pike.
Same in Masonic Review, v. 23, no. 3, June, 1860, p. 165-169.

Arkansas Grand Lodge. Proceedings 1853. Address to all affliated freemasons in the State of Arkansas. Appx. p. 1-7.

Same in "Masonry in Arkansas," p. 94-103.

Report on Masonic law and usage, p. 58-61, 69-71.

Proceedings 1854. Report of edicts, resolutions and decisions of the Grand Lodge, p. 1-15, at back.

Report on Foreign Correspondence, appx. p. 1-138.

Proceedings 1859. Address to the Grand Lodge, p. 48-50.

Same in Western Freemason, v. 4, no. 8, Feb., 1860, p. 253-254.

Proceedings 1860. Address to the Grand Lodge, p. 16-17. *Same in* Masonic Mirror and Keystone, v. 9, no. 48, Nov. 28, 1860, p. 575.

Arkansas Grand Chapter. Proceedings 1853. Report on Foreign Correspondence, appx. p. 46-106. Report on Masonic law and usage, appx. p. 1-45. *Same in* Masonic Mirror and Keystone, v. 3, Nov. 4-17. [Reply of Albert Pike, to Bro. Mitchell's trictures in the "Signet" for April, 1854, on the report of the Committee on Masonic law and usage, in regard to the degrees of Royal and Select Master.] *In* Masonic Mirror and Keystone,, v. 3, nos. 26-28.

Proceedings 1854. Address as Grand High Priest, p. 3-15. *Same in* Masonic Mirror and Keystone, v. 4, nos. 2-5, 1855.

Proceedings 1856. Report on Masonic law and usage, p. 27-33, 40-42.

Proceedings 1859. Report on Masonic law and usage, p. 38-47, 68-71.

An examination of a report of a masonic committee, made at Boston, in May, 1866. [By Albert Pike.] New York, Masonic Publishing and Manufacturing Company, 432 Broome street, 1866. 116+22+2 p. 8°.

Laying a corner-stone (A∴ & A∴ S∴ R∴) at the city of Washington, June 7, 1888. [Washington.] Joseph L. Pearson, printer, [1888.] 19 p. 8°.

P. 4-13 contain an address by Pike.
Same in his Official Bulletins, v. 8, p. 371-379.
Same in Trestle Board, v. 2, no. 9, Sep., 1888, p. 257-261.

Lecture [The evil consequences of schisms and disputes for power in masonry, and of jealousies and dissensions between masonic rites] of Bro∴ Albert Pike, delivered by special request before the M. W. Grand Lodge of Louisiana, at its forty-sixth annual communication, held in New Orleans, February, 1858. Published by order of the Grand Lodge. New Orleans, printed at the Bulletin Book and Job Office, 1858. 68 p. 8°.

Same in Louisiana Grand Lodge, proceedings, 1858, p. 69-135. Masonic Messenger (New Orleans), v. 1, no. 1, July, 1859, p. 2-27.

Same. What masonry is and its objects. Address originally delivered by Albert Pike at the Grand Lodge session of February 8, 1858. Re-delivered by M. W. Brother George A Treadwell, Grand Master, February 4, 1919. New Orleans, A. W. Hyatt Stationery Mrg. Co., Ltd. 1919. 30 p. 8°.

Does not contain the full text of the above "Lecture."

Lecture in the Holy Royal Arch degree *In* Masonic Mason and Keystone, v. 3, nos. 33-37, 1854. Southern and Western Masonic Miscellany, v. 5, nos. 1 and 2, July and August, 1854, p. 11-17, 38-45.

Masonic Veteran Association of the District of Columbia. Transactions, 1879-87, [v. 1.] Address of the President, 1880, p. 20-23. Address of the President, 1881, p. 29-32. Introductory remarks of the President, 1882-83, p. 38-46. Address of the President 1883-84, p. 58-70. Address of the President, 1884-85, p. 78-86. Address of the President, 1885-86, p. 91-98. Address of the President, January 10, 1887, p. 114-129.

Transactions, 1887-1890, v. 2. Address, 9th January, 1888, p. 9-30.

Same. [Extracts.] Trestle Board, v. 3, no. XI, Nov., 1889, p. 321-330; v. 5, no. 10, Oct., 1891, p. 440-447; Voice of Masonry, v. 27, no. 10, Oct., 1889, p. 867-879.
Same in his Official Bulletins, v. 9, p. 321-337.
Same, printed separately: Address of the President [Albert Pike] of the Masonic Veteran Association of the District of Columbia, at the annual meeting, January 9, 1888. Washington, November, 1888. 26 p. 8°.

Address of the President, January 14, 1889, p. 40-51.

Address of the President, January 13, 1890, p. 77-91.

Same, printed separately: Address of the President [Albert Pike] of the Masonic Veteran Association of the District of Columbia, at its annual meeting, January, 1890. Washington, Jos. L. Pearson, printer, 1890. 20 p. 8°.

Addresses of the President [Albert Pike] of the Masonic Veteran Association of the District of Columbia, 1888, 1889, 1890. Washington, Gibson Bros., printers and bookbinders, 1890. 49 p. 8°. [Cover title.]

Oration [Before the Grand Lodge of Odd Fellows of Arkansas,] August 8, 1850. [Little Rock, 1850.] 15+1 p. 8°.

Caption title, "Oration."

Royal Order of Scotland, Provincial Grand Lodge for the United States of of America. Records and minutes, 1879-1890.

Allocution of the Provincial Grand Master, 1879, p. 25-28; 1880, p. 42-44; 1881, p. 56-66; 1882, p. 80-84; 1883, p. 105-110; 1884, p. 141-146; 1886, p. 201-210, 214-220

Same, printed separately: Allocution of the Provincial Grand Master [Albert Pike] for the United States of America. Ninth annual meeting of the Provincial Grand Lodge, Washington, D. C., October 18th, 1886. 21p. 8°.

1887, p. 239-248; 1888, p. 278-281, 294-296; 1889, p. 316-322. *Same in his* Official Bulletins, v. 10, 299-306.

1890, p. 366-387.

St. John's day, Saturday, June 24th, 1871. Address in full of Dr. Albert G. Mackey, and condensed report of Gen. Albert Pike's address, delivered before the masonic fraternity of Sandusky, Ohio, and visiting brethren at Put-in-Bay, Ohio. 8p. 8°.

Supreme Council for the Southern Jurisdiction of the United States. Transactions, 1860-1890.

Address of the Grand Commander [Albert Pike]:

1860 (original), p. 8-57.

(Reprint 1857-66) p. 84-119.

1861 (original 1861-66), Appx. A., p. 3-47.

(Reprint, 1857-66) p. 196-227, 231-242.

1865 (originals, 1861-66), Appx. B, p. 3-102.

(Reprint, 1857-66) p. 257-352.

1866 (originals, 1861-66), Appx. C, p. 1-35.

(Reprint, 1857-66) p. 405-438.

1868, p. 5-65.

Alloquiam of the grand Commander:

1870, Appx., p. 99-168.

Allocution of the Grand Commander:

1872, p. 6-39.

1874, Appx. A, p. 1-69.

1876, p. 4-42.

1878, p. 5-32.

Same in his Official Bulletins, v. 4, p. 3-30. *Same (extracts),* Masonic Record of Western India, v. 17, No. 5, Aug., 1880, p. 183-190.

1880, Appx. No. 1, p. 1-55.

Same in his Official Bulletins, v. 4, p. 395-416.

1882, Appx. A, p. 3-59.

Same, printed separately: Allocution of the Grand Commander [Albert Pike], Transactions of 1882. [Washington.] 62 p. 8°.

1884, Appx. No. 1, p. 3-74.

Same, printed separately: Allocution of the Grand Commander [Albert Pike], October 20, 1884. [Washington.] 74 p. 8°.
Same (extracts) in his Official bulletins, v. 7, p. 8-38; Masonic Review, v. 63, no. 2, Mar., 1885, p. 92-96; Texas Masonic Journal, v. 1, no. 1, Jan., 1886, p. 31-36.

1886, Appx. A, p. 3-54.

Same, printed separately: Allocution of the Grand Commander [Albert Pike], Session of 1886. [Washington.] 54 p. 8°.
Same in his Official Bulletins, v. 8, p. 1-54. [Extracts.] Texas Masonic Journal, v. 1. No. XI, Nov., 1886, p. 387-392.

1888, Appx. A, p. 1-40.

Same in his Official Bulletins, v. 9, Appx. p. 1-40.

1890, Appx., p. 1-54.

Same, printed separately: Allocution of the Grand Commander [Albert Pike] of the Supreme Council of the 33d degree of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction of the United States, at its triennial session, October 20, 1890. Washington, Jos. L. Pearson, printer, 1890. 54 p. 8°.

Same [extracts]. Voice of Masonry, v. 29, No. 3, Mar., 1891, p. 212-217.

Report of the Sovereign Commander [Albert Pike] on the difficulties at St. Joseph, Missouri. *In* Supreme Council Southern Jurisdiction, Transactions 1870, p. 256-258.

The turnpike of life. *In* Mackey's National Freemason, v. 1, June, 1872, p. 452-453.

Being his response to a toast to which he was appointed to reply at the annual banquet of Lafayette Chapter, R. A. M., of the District of Columbia, December 19, 1872, the toast being to the life members of the Chapter and alluding to the turnpike of life.

What freemasonry was. Read at the meeting of the Masonic Veteran Association [of the District of Columbia] in February, 1887. [By Albert Pike.] *In* Transactions of the Association, p. 135-204.

What of the night. The lesson of the Order of the Temple and of the Rose Croix. An address at a Lodge of Sorrow, in Louisville, Ky. *In* Voice of Masonry, v. 27, No. 6, June, 1889, p. 498-505.

OBITUARIES.

(General)

Address. *In* Louisiana Grand Consistory, Ceremony of the Lodge of Sorrow, New Orleans, November 10, 1869, p. 4-8.

Address. At a Lodge of Sorrow. *In* Transactions of the Supreme Council, 1874, p. 84-89. Brownell, J. H., Gems from the quarry, v. 2, p. 166-168.

Eulogy. *In his* Official Bulletins, v. 4, p. 451-457. Transactions Supreme Council, 1880, p. 34-40.

Homage to the illustrious dead of Kentucky, pronounced by Albert Pike, at the Lodge of Sorrow, held at Louisville, Kentucky, June 17, 1875. Washington, printed by W. H. Moore, 511 11th street, 1875. 14p. 8°.

Same in Masonic Newspaper [Extracts], v. 1, no. 37, June 14, 1879, p. 168-169; Masonic Eclectic, v. 1, no. 12, June, 1877, p. 553-559; Pike Albert. Official Bulletins, v. 3, p. 70-81.

Tribute of affection. *In* Masonic Jewel, v. 2, No. 6, June 15, 1872, p. 93-95. Transactions of the Supreme Council, 1872, p. 143-148.

A general tribute to the dead.

Words of truth spoken of the dead. *In* Transactions of the Supreme Council, 1876, p. 86-94.

Ex corde locutiones. Words from the heart spoken of his dead brethren, by the Grand Commander [Albert Pike] of the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. 1860 to 1891. [Press of J. J. Little & Co., New York, copyright, 1899.] Port. 8+358p. 8°.

Edited by Joseph C. Taylor, 33°, Hon .
The work in the main is a compilation of the obituary notices issued by Pike at various times, over his signature, either printed, stamped or autographed. The notices are prefaced in official form. The subjects of the obituaries appear only in the text of the notices. The following is a list of them arranged alphabetically:

(Individual)

Ames, Alfred Elisha, William Martin Perkins and Augustus Frederick Fitzgerald. Washington, October 7, 1874. [3]p. Wide. 8°.

Same in his Official Bulletins, v. 2, pt. 3, p. 23-27.

Barber, Luke Edgar. Washington, June 21, 1886. [3]p. Wide. 8°.

Same in his Official Bulletins, v. 8, p. 11-14. Texas Masonic Journal, v. 1, no. 8, Aug., 1886, p. 282-285.

Bérard, Eugène-Charles. Washington, March 24, 1890. *In his* Official Bulletins, v. 10, p. 67-68.

Blackie, George Stodart. Washington, June 23, 1881. [1]p. Wide. 8°.

Same in his Official Bulletins, v. 5, p. 5-6.

Breckenridge, John C. *In* James, J. G. Southern student's handbook of selections for reading and oratory, p. 103-105. *From his:* "Homage to the dead of Kentucky."

Buist, Henry. Washington, June 10, 1887. [2]p. Wide. 8°.

Same in his Official Bulletins, v. 8, p. 19-23. Texas Masonic Journal, v. 2, no. 7, July, 1887, p. 229-233.

Campbell, Benjamin Rush. Washington, November 27, 1874. [2]p. Wide. 8°.

Same in his Official Bulletins, v. 2, part 3, p. 43-45.

Christie, John. Washington, January 8, 1890. [2]p. Wide. 8°.

Same in his Occasional Bulletins, no. 10, p. 51-52. Official Bulletins, v. 9, p. 7-9. Ohio Council of Deliberation, Proceedings, 1891, p. 23-24.

Corson, Thomas J. Washington, January 8, 1880. [1]p. Wide. 8°.

Same in his Official Bulletins, v. 4, p. 57-58.

Cothran, William and William Gustav Emile Tonn. Washington, February 7, 1881. [1] p. Wide. 8°.

DeSaussure, Wilmot Gibbes, Washington, February 4, 1886. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 7, p. 530-534.

Etter, Daniel Frank. [Washington, 1890.] *In his* Official Bulletins, v. 10, p41-42.

Fondey, Townsend, and Robert Farmer Bower. Washington, June 19, 1882. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 5, p. 365-366.

French, Benjamin Brown. Washington, August 12, 1870. [1] p. 8°.

Same in his Official Bulletins, v. 1, p. 146-148.

Furman, Charles Manning. Washington, July 10, 1872. [2] p. Wide. 8°.

Garfield, James Abram. Notice of his serious illness from the assassin's bullet, which culminated in his death. Mimeographed. Washington, July 11, 1881. [2] p. Wide. 8°.

Girard, Michel Eloi. Washington, May 3, 1889. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 9, p. 344-347.

Gould, William Tracy, Washington, December 15, 1882. *In his* Official Bulletins, v. 5, p. 431-432.

Graham, Robert McCrosky. Washington, March 10, 1891. [2] p. Wide. 8°.

Harington, Thomas Douglas. Charleston, January 14, 1882. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 5, p. 13-14.

Harris, William Augustus. [Washington, 1890?] *In his* Official Bulletins, v. 10, p. 36-38.

Hieston, Jacob Castle. [Washington] January 16, 1884. *In his* Official Bulletins, v. 6, p. 44-445.

Hillyer, Giles Mumford. Washington. [May 21, 1871.] [1] p. Wide 8°.

Same in The Evergreen, v. 4, no. 7, July, 1871, p. 329-330. Pike. Official Bulletins, v. 1, p. 341-343.

Honour, John Henry. Charleston, November 27, 1885. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 7, p. 525-527.

Hort, William, Arthur Bushe, George Chatterton, and Joannes G. Papadakis. Washington, April 24, 1877. [3] p. Wide. 8°.

Hubbard, Horace Halsey, and Robert Farmer Bower. Charleston [about 1882]. [2] p. Wide. 8°.

Same in his Official Bulletins, v. 5, p. 362-365.

Ives, Edward Rutledge. Washington, 13th day of the Hebrew month (adar) A∴M∴ 5630 [1870]. [2] p. 8°.

Same in Transactions of Supreme Council 1870, p. 227-228.

Keyser, Edward S. Washington, March 14, 1881. [2] p. Wide 8°.

Laffon de Ladebat, Charles Joseph. Washington, January 20, 1883. [2] p. Wide 8°.

Same in his Official Bulletins, v. 5, p. 433-434.

Lewis, John Lawson. Charleston, May 22, 1886. [2] p. Wide 8°.

Same in his Official Bulletins, v. 8, p. 9-11. Texas Masonic Journal, v. 1, no. 7, July, 1886, p. 241-243.

Lewis, John Livy. Washington, June 17, 1889. [1] p. Wide 8°.
Same in his Official Bulletins, v. 9, p. 347-349.

McDaniel, John Robin. Washington, May 15, 1878. [3] p. Wide 8°.
Same in his Official Bulletins, v. 4, p. 42-43. Transactions Supreme Council, 1878, p. 69-72.

Mackey, Albert Gallatin. Washington, June 24, 1881. [2] p. Wide 8°.
Same in his Official Bulletins, v. 5, p. 6-8.

Mackey, Albert Gallatin. Washington, June 24, 1881. [1] Wide 8°.
Same in his Official Bulletins, v. 5, p. 57-58.

McMasters, Sterling Y. Washington, November 10, 1875. [3] p. 8°.
Same in his Official Bulletins, v. 3, p. 6-9.

Maude, John Burton. Washington, May 8, 1879. [2] p. Wide 8°.
Same in his Official Bulletins, v. 4, p. 50-52.

Melville, John Whyte. Charleston, October 9, 1883. [2] p. Wide 8°.
Same in his Official Bulletins, v. 6, p. 6-8.

Milbitz, Allessandro Isenschmid de. Charleston, October 9, 1883. [2] p. Wide 8°.
Same in his Official Bulletins, v. 6, p. 4-6.

Millis, James Wesley. Washington, September 9, 1883. [3] 8°.
Same in his Official Bulletins, v. 7, p. 523-525.

Mitchell, William Letcher. Charleston, November 1, 1882. [2] p. Wide 8°.
Same in his Official Bulletins, v. 5, p. 429-430.

Murray, James Charles Plantagenet. Washington, August 9, 1874. [2] p. 8°.

Noyes, Samuel Verrill. [Washington, February, 1886.] [By Albert Pike.] Cover title: "In Memoriam." 11 p. 8°.
Same in his Official Bulletins, v. 7, p. 573-577.

O'Sullivan, Anthony. Memphis, Tenn., 4th day of . . A∴M∴ 5626 [1866]. [1] p. Wide 8°.

Pearson, Joseph Lawson. [Washington, September 14, 1882.] [By Albert Pike.] 9 p. 8°. Cover title: "In Memoriam."
Same in his Official Bulletins, v. 5, p. 511-514.

Penn, James. Washington, August 2, 1870. [1] p. 8°.
Same in his Official Bulletins, v. 1, p. 141-142.

Pierson, Azariah T. C. Washington, November 27, 1889. [2] p. Wide 8°.
Same in his Occasional Bulletins, no. 10, p. 3-5.

Poore, Ben Perley. Washington, May 29, 1887. [3] p. Wide 8°.
Same in his Official Bulletins, v. 8, p. 15-18. Texas Masonic Journal, v. 2, no. 6, June, 1887, p. 196-199.

Quitman, John Anthony. An address on the actions and character of John Anthony Quitman, Sovereign Grand Inspector General, 33d degree. [By Albert Pike.] N. p. [1860.] 25 p. 8°.
Same in Transactions of Supreme Council (Original), 1860, p. 76-99.
Same in same (Reprint), 1857-66, p. 134-150.
Same. Extract from an address on. *In* American Freemasons Magazine, v. 6, no. 32, August, 1860, p. 79-84.
See also Manuscripts: Quitman, John Anthony.

Ramsay, David, John Siegling, and Achille LePrince. *In* Transactions of Supreme Council, 1868, Supplement, p. 21-26.

Richardson, Benjamin Ball. Washington, February 17, 1880. [2] p. Wide 8°.
Same in his Official Bulletins, v. 4, p. 378-380.

Riche, Léopold. Washington, D. C., March 20, 1885. *In his* Official Bulletins, v. 7, p. 142-143.

Rockwell, William S. Washington, 22nd day of the Hebrew month Tebeth, A∴M∴ 5630 [1870]. [3] p. 8°.

Same in Transactions of Supreme Council, 1870, p. 226-227.

Roome, Charles. Washington, June 29, 1890. [2] p. Wide 8°.

Same in his Official Bulletins, v. 10, p. 548-551.

Ruchonnet, Francois Louis, Francis Robert St. Claid Erskine, and William James Bury McLeod Moore. Washington, September 20, 1890. [2] p. Wide 8°.

Same in Herald of Masonry, v. 1, no. 3, Dec., 25, 1890, p. 25.

Samory, Claude Pierre. Washington, August 10, 1889. [2] p. Wide 8°.

Same in his Official Bulletins, v. 9, p. 349-352.

Scruggs, Daniel Edward. Washington, November 9, 1871. [2] p. Wide 8°.

Same in his Official Bulletins, v. 1, p. 352-354.

Shaw, Ebenezer Hamilton. Washington, February 21, 1876. [3] p. Wide 8°.

Same in his Official Bulletins, v. 3, p. 9-12.

Smith, Jonathan Moody, and Zebulon Montgomery Pike. Washington, July 31, 1877. [3] p. Wide 8°.

Spofford, Richard S. Washington, January 22, 1872. *In his* Official Bulletins, v. 1, p. 554-556.

Tonn, Gustav Emile. Washington, January 27, 1881. [2] p. Wide 8°.

Same in his Official Bulletins, v. 4, p. 699-700.

Toombs, Robert. Charleston, December 17, 1885. [2] p. Wide 8°.

Same in his Official Bulletins, v. 7, p. 527-530. Texas Masonic Journal, v. 1, no. 1, Jna., 1886, p. 7-10.

Tucker, Philip C. *In* Mackey's National Freemason, v. 2, May, 1873, p. 397-403.

Van Humbeék, Pierre. Washington, July 18, 1890. [2] p. Wide 8°.

Same in his Official Bulletins, v. 10, p. 558-560.

Vigne, Charles John, Angel Martin and William Leffingwell. Washington, June 25, 1877. [2] p. Wide 8°.

Same in his Official Bulletins, v. 3, p. 362-364.

Watson, Hugh Parks, and Anthony O'Sullivan. Memphis, Tenn., 4th day of . . . A∴M∴ 5626 [1866]. *In* Transactions of Supreme Council, 1868, p.62-63.

Wheat, John Thomas In memoriam. Washington, February 7, 1888. *In his* Official Bulletins, v. 8, p. 348-350.

Worsham, John Jennings. Washington, 16th day of Ab. A∴M∴ 5631 [1871]. [2] p. Wide 8°.

Same in his Official Bulletins, v. 1, p. 347-349.

OFFICIAL LETTERS AND NOTICES.

354, May 13, Little Rock, Ark. Letter to W. T. Gould, subject: Grand Chapters and the General Grand Chapter. *In* Southern and Western Masonic Miscellany, v. 5, no. 2, Aug., 1854, p. 48-49.

359, December 27, Charleston, S. C. [2] p. folio. Address to the Supreme Councils of the world regarding representatives, uniformity of work and general fraternal intercourse.

360, February 24, Washington, D. C. [1] p. Wide 8°. Notice to attend adjourned session of the Supreme Council, March 28, 1860.

365, July 15, Charleston, S. C. [3] p. Wide 8°. Settlement of the dissentions in the two Supreme Councils of the Northern Jurisdiction of the United States.

365, October 27, Charleston, S. C. [1] p. Wide 8°. Legitimacy of the Supreme Council for Cuba and the Antilles.

366, January 8, Charleston, S. C. [3] p. Wide 8°. Notice of meeting of the Supreme Council, 1866.

366, February 16, Charleston, S. C. 7 p. 8°. Legitimacy of the two contending Supreme Councils of the Northern Jurisdiction of the United States.

366, March 4, Charleston, S. C. [1] p. folio. Appointing Richard H. Hartley, Special Representative near the Supreme Council of Peru, and authorizing him to confer the Scottish Rite degrees in Ecuador, Bolivia, and Chile.

66, March 5, Charleston, S. C. [1] p. folio. Notice to several Supreme Councils of the appointment of Richard H. Hartley, as per preceding circular.

66, March 12, Memphis, Tenn. [1] Wide 8°. Notice of meeting of the Supreme Council for the 3rd Monday in April, postponed from the 3rd Monday in February.

67, September 1, Charleston, S. C. [1] p. folio. Invasion of rights of the Supreme Council, Southern Jurisdiction, U. S. A., by the Supreme Council of Belgium.

Same in Transactions of the Supreme Council, 1868, p. 205-208. Freemasons Monthly Magazine, v. 27, no. 1, Nov. 1, 1867, p. 9-11.

67, [September 26] Memphis, Tenn. [1] p Wide 8°. Qualifications necessary to receive the Scottish Rite degrees.

Same in Transactions of the Supreme Council, 1868, p. 189-190. Official Bulletins of the Supreme Council, v. 1, p. 91-92.

67, [. . .] St. Louis, Mo. [1] p. Wide 8°. Conferring of degrees by bodies of the Northern Jurisdiction on candidates of the Southern Jurisdiction.

67, [. . .] Memphis, Tenn. Controversy with George Frank Gouley. *In* Transactions, Supreme Council, 1868, p. 191-195; National Freemason, v. 9, no. 18, November 2, 1867, p. 285.

68, [about April 2] Memphis, Tenn. [1] p. Wide 8°. Notice of Supreme Council meeting at Charleston, May 4, 1868.

68, June 30, Charleston, S. C. [1] p. folio. Findings of the tribunal *in re* charges against George Frank Gouley.

68, August 15, Charleston, S. C. [1] p. folio. Notice of meeting of Supreme Council at St. Louis and Lodge of Sorrow to be held there.

1868, [. . .] [Memphis, Tenn?] [1] p. Wide 8°. Inspectors General and Deputies to make financial returns for degrees conferred.

1868, [. . .] Memphis, Tenn. [1] p. 8°. Asking for vote on the question of statutory delays between degrees.

1869, March 1, Charleston, S. C. 15 p. 8°. Letter of denunciation and appeal jointly by the Northern and Southern Supreme Councils against the Supreme Council for Louisiana, James Foulhouze and the Grand Orient of France. French and English text.

1869, March 1 and 8, Charleston, S. C. and Boston, Mass. Circular issued by Albert Pike and Josiah H. Drummond, Grand Commanders of the Northern and Southern Supreme Councils regarding the Grand Orient of France and the spurious Louisiant Supreme Council. Franch and English text. *In* Transactions Supreme Council 1868, p. 227-236; Transactions 1870, p. 181-180, 258-268, 280-284.

1869, April 21, Charleston, S. C. Revocation of the edict against the Supreme Council of Belgium. *In* Transactions of the Supreme Council, 1868, p. 219-220.

1869, April 30, Charleston, S. C. Legitimacy of the Supreme Council of Brazil, with *See* at Lavradio. *In* Transactions Supreme Council 1868, p. 220-222.

1870, [February 1], Washington, D. C. [2] p. Wide 8°. Conferring the degrees in too short a time and requiring the statutes to be observed in this connection.

Same in Transactions Supreme Council, 1870, p. 180-181.

1870, [March . .], Washington, D. C. [2] p. Wide 8°. Notice of meeting of Supreme Council and of a Lodge of Sorrow to be held.

Same in Transactions Supreme Council, 1870, p. 168-170.

1870, [May? . . Washington, D. C.] [2] p. 8°. Requesting vote on statute regarding Court of Honour.

1870, May 2, Charleston, S. C. 11 p. 8°. Letter of denunciation and appeal issued jointly by the Northern and Southern Supreme Councils against the Supreme Council for Louisiana, James Foulhouze and the Grand Orient of France.

1870, May 2, Charleston, S. C. 39 p. 8°. Letter of denunciation and appeal issued jointly by the Northern and Southern Supreme Councils againsa the Supreme Council for Louisiana, James Foulhouze and the Grand Orient of France, together with an appendix containing copies of letters, etc., of the Grand Orient of France, in French.

Same in his Official Bulletins, v. 1, p. 61-90.

1870, [June . .], Washington, D. C. [1] p. Wide 8°. Regarding returns or reports to the Supreme Council.

1870, July 14, Washington, D. C. [1] p. Wide 8°. Ritualistic matters.

1870, [July? . .], Washington, D. C. [1] p. Wide 8°. Regarding blank form to be appended to the ritual.

1870, December 19, Washington, D. C. [2] p. Wide 8°. Notifying that A. T. C. Pierson has no power to confer the degrees.

Same in The Evergreen, v. 4, no. 2, Feb., p. 90.

1871, January 1, Washington, D. C. [2] p. Wide 8°. Information for Inspectors and Deputies regarding conferring the Scottish Rite degrees.
Same in his Official Bulletins, v. 1, p. 155-157.

1871, January 5. Revoking his order of December 19, 1870, *in re* A. T. C. Pierson. *In* The Evergreen, v. 4, no. 3, March, 1871, p. 138.

1871, February 28, Washington, D. C. [1] p. 8°. Raising money for printing expenses.

1871, [About April 20], Washington, D. C. [1] p. 8°. Photograph cards of cipher.

1871 [June? . .] Washington, D. C. [2] p. 8°. Fees where there is a Grand Consistory.
Same in his Official Bulletins, v. 1, p. 355-356.

1871, October 25, Charleston, S. C. [3] p. Wide 8°. Regulations for the settlement of accounts.
Same in his Official Bulletins, v. 1, p. 363-364.

1871, November 10, Washington, D. C. [2] p. Wide 8°. Asking for aid for brethren of the Rite, sufferers from a calamity in Illinois, Michigan and Wisconsin.
Same in his Official Bulletins, v. 1, p. 364-365.

1872, March 10, Washington, D. C. [2] p. Wide 8°. Publication and expense of his ''Book of the Words.''

1872, March 11, Washington, D. C. [2] p. Wide 8°. Changing place of meeting of Supreme Council in 1872 from San Francisco to Louisville.
Same in his Official Bulletins, v. 1, p. 580-582.

1872, March 20, Washington, D. C. [1] p. 8°. Completion of his ''Morals and Dogma,'' and their distribution.

1872, April 2, Washington, D. C. [1] p. Wide 8°. Nominations for the Court of Honour.

1872, June 15, Washington, D. C. [4] p. Wide 8°. Home for the Supreme Council.
Same in his Official Bulletins, v. 2, p. 17-18.

1872, November 28, Charleston, S. C. [2] p. Wide 8°. Disclaiming any conflict of the Scottish with the York Rite, etc.
The printed date is December 28, 1872, but was corrected to "November 28."
Same in Transactions of Supreme Council, 1874, appx. 73-75.

1872, December 16, Charleston, S. C. [2] p. Wide 8°. Conference of Supreme Councils proposed to be held in May, 1874.
Same in his Official Bulletins, v. 2, p. 10-11.

1872, December 28, *see* 1872, November 28.

1873, January 9, Washington, D. C. [1] p. Wide 8°. Asking for restoration to membership of George Frank Gouley.
Same in his Official Bulletins, v. 2, p. 17.

1873, February 28, Washington, D. C. 11 p. 8°. Letter to Josiah H. Drummond, regarding Andres Cassard, 33°, in connection wits Scottish Rite matters.

1873, May 8, Washington, D. C. [2] p. Wide 8°. Stock in the Scottish Rite Sanctuary.

1873, June 17, Charleston, S. C. Regarding meeting of the Supreme Councils of the world. *In* Transactions of Supreme Council, 1874, appx. p. 75-76.

1874, January [. . .], Washington, D. C. Regarding Congress of Supreme Councils. *In* Transactions of Supreme Council, 1874, appx. p. 77.

1874, February 22, Washington, D. C. Regarding West Indies Supreme Councils. *In* Transactions of Supreme Council 1874, appx. p. 86-91.

1874, March 27, Washington, D. C. [2] p. Wide 8°. Notice of vote to change meeting of the Supreme Council to Washington in May, 1874.

1874 [June? . .], Washington, D. C. [1] p. 8°. Regarding publishing "Lecture on Masonic Symbolism."

1874, September 16, Washington, D. C. [2] p. Wide 8°. Embodying a communication from the Supreme Council of Belgium.

1874, October 9, Washington, D. C. [2] p. Wide 8°. Conferring of the Scottish Rite degrees by an Active Member or Deputy without observance of statutory delays, etc.

Same in his Official Bulletins, v. 2, p. 30-32.

1874, December 12, Washington, D. C. [1] p. Wide 8°. Forwarding copy of his "Lecture on Masonic symbolism," with data of cost of its printing, and reference to his Second Lecture.

1874, December 15, Washington, D. C. 8 p. 8°. Submitting Articles of Confederation between Supreme Councils, to vote in recess.

1875, February 24, Washington, D. C. [2] p. Wide 8°. Submitting statutes and rules regarding finances of the Supreme Council.

Same in his Official Bulletins, v. 3, p. 14-17.

1875, April 5, Washington, D. C. [1] p. 8°. Regarding publication of his Second lecture on Masonic symbolism.

1875, July 2, Washington, D. C. [2] p. Wide 8°. Establishment by the Supreme Council of France of a lodge in Honolulu, Hawaii, and the establishment by the Supreme Council, Southern Jurisdiction, of a Lodge of Perfection there and embodying copy of a letter from Supreme Council of France.

Same in his Official Bulletins, v. 3, p. 26-27.

1875, August 16, Washington, D. C. [4] p. Wide 8°. Same subject and embodying another letter from the Supreme Council of France.

Same in his Official Bulletins, v. 3, p. 30-35.

1875, November 8, Washington, D. C. [2] p. Wide 8°. Same subject.

Same in his Official Bulletins, v. 3, p. 35-37.

1875, November 19, Washington, D. C. [2] p. Wide 8°. Same subject, and the Articles of Alliance of Confederation of Supreme Councils.

Same in his Official Bulletins, v. 3, p. 38-40.

1875, November 20, Washington, D. C. Regarding publication of his Second lecture on masonic symbolism. *In* Masonic Chronicle, 1. 1, no. 9, January, 1876, p. 144-145.

1876, February 2, Washington, D. C. [4] p. Wide 8°. Same subject of his controversy with Supreme Council of France, above noted.

Same in his Official Bulletins, v. 3, p. 46-52.

1876, March 5, Charleston, S. C. [3] p. Wide 8°. Forming another union of Supreme Councils from that of the Lausanne congress.

1876, Mach 20, Charleston, S. C. [2] p. Wide 8°. Same subject.
Same in his Official Bulletins, v. 3, p. 52-55.

1876, April 18, Washington, D. C. [1] p. Wide 8°. Notice of meeting of the Supreme Council.

1876, May 13, Washington, D. C. [2] p. Wide 8°. Closing dispute with the Supreme Council of France.
Same in his Official Bulletins, v. 3, p. 55-56.

1877, June 25, Washington, D. C. [2] p. Wide 8°. Proposing the creation of a Printing Fund.

1877, June 25, Washington, D. C. [2] p. Wide 8°. Calling attention to certain portions of the law of the Supreme Council.
Same in his Official Bulletins, v. 3, p. 380-381.

[1877, about June], Washington, D. C. [1] p. Wide 8°. List of books for sale by the Supreme Council, and note thereon.

1877, August 2, Washington, D. C. [4] p. Wide 8°. Supreme Council of Scotland and the League of Supreme Councils distinct from that at Lausanne, and embodying a letter from the Supreme Council of England and Wales.
Same in his Official Bulletins, v. 3, p. 445-449.

1877, October 19, Charleston, S. C. 19 p. 8°. Dei optimi maximi, universitatis rerum fontis ac originis ad gloriam majoref. [Signed: Albert Pike.] Or[ient] of Charleston, So. Carolina, October, 1877. [Printed at Washington, D. C.]
Text is in English. Relates to the action of the Grand Orient of France in its concessions to atheism.
Same in his Official Bulletins, v. 3, p. 514-529.

1878, January 1, Washington, D. C. [2] p. Wide 8°. Printing Fund.
Same in his Official Bulletins, v. 3, p. 382-384.

1878, March 27, Washington, D. C. [1] p. Wide 8°. Notice of Meeting of the Supreme Council.

1878, March 30, Washington, D. C. [2] p. 8°. Notice of organization of the Provincial Grand Lodge, Royal Order of Scotland.

1878, May 27, Washington, D. C. Recalling commission of Henry St. George Hopkins, etc.
In his Official Bulletins, v. 4, p. 49. Transactions of Supreme Council, 1878, p. 75.

1878, June 12, Washington, D. C. [1] p. Wide 8°. Asking for photographs of all the Active members of the Supreme Council.

1878, June 12. Early history of the Scottish Rite especially the Southern Jurisdiction. *In* Masonic Review, v. 51, no. 8, September, 1878, p. 352-357.

1878, June 20, Washington, D. C. [2] p. Wide 8°. Appeal for aid for printing books.
Same in his Official Bulletins, v. 4, p. 58-60.

1878, July 22, Washington, D. C. [1] p. Wide 8°. Notice of election of J. C. Batchelor as Lieut. Grand Commander, etc.

1878, August 2, Washington, D. C. [2] p. Wide 8°. Supreme Council of Cuba and the creation of Supreme Councils in general.

1879, January 1, Washington, D. C. [1] p. Wide 8°. Simplification of titles.

1879, March 15, Charleston [Washington]. 21 p. 8°. "Titles of degrees, bodies and officers of the Ancient and Accepted Scottish Rite, to be used hereafter in the Southern Jurisdiction of the United States. Charleston [Washaington.] 20 Adar, 5639 [1879]."

1880, January 3, Washington, D. C. [1] p. Wide 8°. Regarding issuance of diplomas of the 14°. Mimeographed.

1880, February 3, Washington, D. C. [1] p. Wide 8°. Regarding establishment of a Consistory at Minneapolis. Mimeographed.

1880, February 15, Washington, D. C. [1] p. 8°. Regarding the official Bulletin of the Supreme Council.

1880, March 31, Washington, D. C. [2] p. 8°. Regarding the Cerneau Scottish Rite and embodying a letter from R. M. C. Graham of the Northern Supreme Council on the subject.

Same in his Official Bulletins, v. 4 ,p. 391-392.

1880, September 1, Charleston, S. C. [1] p. Wide 8°. Notice of meeting of the Supreme Council, 1880.

1880, November 15, Washington, D. C. [1] p. Wide 8°. Giving instructions and forms for filling in the proper data for use in compiling a Register of membership.

1881, March 31, Washington, D. C. [1] p. Wide 8°. Asking for a vote on the restoration to membership of Henry H. Neal, 33°, Hon. Mimeographed.

1881, April 27, Washington, D. C. [1] p. folio. Establishment in Florida of Cerneauism.

Same in his Official Bulletins, v. 5, p. 19-20.

1881, June 25, Washington, D. C. [1] p. 8°. Appointment of Wm. M. Ireland as Secretary General of the Supreme Council.

Same in his Official Bulletins, v. 5, p. 26-27.

1881, August 16, Charleston, S. C. [1] p. folio. Recognition of the Supreme Council of Tunis.

Same in his Official Bulletins, v. 5, p. 179-180.

1881, September 1, [Washington, D. C.] 12 p. 8°. A letter from the Grand Commander [Albert Pike] of the Supreme Council, 33d for the Southern Jurisdiction, U. S. A. to the Grand Master of the Kadosh of Maryland.

Relates to difficulties in Scottish Rite masonry in Maryland.

1881, September 6, Charleston, S. C. [2] p. Wide 8°. Regarding the Grand Consistory of Maryland requiring candidates for the Rite to be Knights Templar.

1881, October 15, Washington, D. C. [1] p. 8°. Regarding returns or reports to the Treasurer General of the Supreme Council.

Same in his Official Bulletins, v. 5, p. 374.

1882, January 3, Washington, D. C. [3] p. Wide 8°. Commending a plan for the establishment of the Garfield Masonic Memorial Institute, and embodying a letter from those proposing the plan.

1882, January 10, Charleston, S. C. [1] p. Wide 8°. Regarding a home for the Supreme Council.

1882, March 28, Washington, D. C. [1] p. Wide 8°. Same subject.

1882, June 30, Washington, D. C. [2] p. Wide 8°. Suspension of the bodies o[illegible] the Rite in Augusta, Georgia.

1882, July 10, Washington, D. C. [1] p. Wide 8°. Regarding reports of Activ[illegible] members of the Supreme Council.

Same in his Official Bulletins, v. 5, p. 375-376.

1882, July 30, Washington, D. C. [1] p. Wide 8°. Legitimacy of the two contending bodies of the Rite in Spain.

1882, July 31, Washington, D. C. [2] p. Wide 8°. Transmitting a letter regarding Cerneauism in Canada.

1882, August 20, Washington, D. C. [2] p. Wide 8°. Regarding the Home o[illegible] Building Fund of the Supreme Council.

1882, September 1, Charleston, S. C. [2] p. Wide 8° Regarding the approaching session of the Supreme Council, 1882.

1883, February 25, Charleston, S. C. [1] p. folio. Recognition of the Supreme Council of Spain.

Same in his Official Bulletins, v. 5, p. 457-458.

1883, March 19, Washington, D. C. [2] p. Wide 8°. Purchase of a home or House of the Temple for the Supreme Council.

Same in his Official Bulletins, v. 5, p. 452-454.

1883, May 16, Washington, D. C. [1] p. Wide 8°. Presentation of a cabinet of minerals by Thomas H. Caswells.

Same in his Official Bulletins, v. 5, p. 487-488.

1883, June 4, Charleston, S. C. [2] p. Wide 8°. Expulsion of certain members for joining the Cerneau Scottish Rite.

Same in his Official Bulletins, v. 5, p. 488-490.

1883, October 31, Charleston, S. C. 13 p. 8°. Legitimacy of the Supreme Council of Cuba.

Same in his Official Bulletins, v. 6, p. 87-95.

1883, October 31, Charleston, S. C. [1] p. Wide 8°. Expulsion of Frederick Widdows for joining Cerneau Scottish Rite.

Same in his Official Bulletins, v. 6, p. 16-17.

1883, November 1, Charleston, S. C. [2] p. Wide 8°. Spurious Scottish Rite bodies.

1883, November 1, Charleston, S. C. [2] p. Wide 8°. Regarding the connections of certain named members in Washington, D. C., with the spurious Scottish Rite.

Same in his Official Bulletins, v. 6, p. 15-16.

1884, January 1, Washington, D. C. [1] p. Wide 8°. Issuance of certificates to the wives, daughters, etc., of Scottish Rite masons.

Same. [1] p. Wide 8°. Another edition varying slightly in the wording.

Same. [1] p. Wide 8°. Another edition varying slightly in the wording.

Same in his Official Bulletins, v. 6, p. 28-29.

1884, February 27, Washington, D. C. [3] p. Wide 8°. Regarding the Home or House of the Temple of the Supreme Council and the erection of a library building.

Same in his Official Bulletins, v. 6, p. 524-526.

1884, May 9, Charleston, S. C. [2] p. Wide 8°. Regarding the Cerneau Scottish Rite.

1884, May 9, Washington, D. C. [3] p. Wide 8°. Regarding difficulties in Maryland, of the Scottish Rite.

1884, May 9, Washington, D. C. [2] p. Wide 8°. Regarding spurious Scottish Rite bodies and certain pamphlets issued by Pike thereon.

1884, July 1, Washington, D. C. [1] p. Wide 8°. Regarding Cerneau Scottish Rite Supreme Councils.

1884, July 1, Washington, D. C. [1] p. Wide 12°. A reissue of the preceding circulated through Oregon being countersigned by "R. P. Earhart, Inspector General, Oregon."

1884, July 1, Washington, D. C. [2] p. Wide 8°. Regarding the desertion of members named, from the Grand Consistory of Maryland to the Cerneau Scottish Rite.

1884, August 1, Washington, D. C. [2] p. Wide 8°. Regarding the approaching session of the Snpreme Council, 1884, and information in connection with the same.

1884, August 15, Washington, D. C. [1] p. Wide 8°. Regarding the Cerneau Consistory at Baltimore and transmitting the names of its members.

1884, August 16, Washington, D. C. [2] p. folio. Extract from a letter of Bro∴ Albert Pike, 33°, Grand Commander of the Supreme Council for the Southern Jurisdiction, to Bro∴ . . . at Minneapolis, Minnesota.

1884, August 25, Washington, D. C. [2] p. Wide 8°. Transmitting names of members of spurious Scottish Rite in California.

1884, August 25, [Washington, D. C.] 11 p. 8°. Extract from a letter of Bro∴ Albert Pike, 33° . . . to Bro∴ Henry M. Aiken, 32°, Deputy of the Sup[reme] Council for East Tennessee. [Washington] 1884.

Relates to the "Cerneau" controversy.

1884, October 27, Washington, D. C. Letter to John H. Honour, former Sov∴ Grand Commander conveying regards and testimonial presented by the Supreme Council. *In his* Official Bulletins, v. 7, p. 99-100. Texas Freemason, February, 1885, p. 117.

1885, January 1, Washington, D. C. [2] p. Wide 8°. Regarding a fund of fraternal assistance.

Same in his Official Bulletins, v. 7, p. 116-119.

1885, January 5, Charleston, S. C. [2] p. Wide 8°. Regarding the Supreme Council of Colon (Cuba).

Same in his Official Bulletins, v. 7, p. 121-124.

1885, January 6, Washington, D. C. [1] p. Wide 8°. Regarding publication of a Register of Membership.

Same in his Official Bulletins, v. 7, p. 125-126.

1885, February 25, Washington, D. C. [1] p. Wide 8°. Requesting a vote on the question of establishing a Consistory in Maryland. Mimeographed.

1885, March 20, Washington, D. C. [1] p. Wide 8°. Regarding fund of fraternal assistance.

1885, September 9, Washington, D. C. [1] p. Wide 8°. Regarding letters lost or stolen in the mails.

1885, September 10, Charleston, S. C. [4] p. Wide 8°. Decision on the question of residence or domicile.

1885, September 15, Washington, D. C. [2] p. Wide 8°. Regarding the conferring of the degrees of the Scottish Rite in groups for the purpose of forming a new body.

Same in his Official Bulletins, v. 7, p. 546-548.

1885, September 26, Charleston, S. C. [1] p. folio. Scottish Rite masonry in Guatemala and the Supreme Council of Costa Rica.

Same in his Official Bulletins, v. 7, p. 549-550.

1885, September 28, Washington, D. C. [2] p. Wide 8°. Scottish Rite masonry in California and Edwin A. Sherman, claiming to be Special Deputy.

1885, October 20, Washington, D. C. [1] p. Wide 8°. Expulsion of Franklin P. Keesee from the Scottish Rite.

Same in his Occasional Bulletins, No. 10, p. 64-65. Official Bulletins, v. 7, p. 554-555.

1885, October 25, Washington, D. C. [4] p. folio. Answering attacks on him from Cerneau Scottish Rite sources.

1885, November 30, Washington, D. C. [2] p. Wide 8°. To the several Supreme Councils, regarding Edward W. Atwood and his spurious Supreme Council.

Same in Official Bulletins of Supreme Council, v. 7, p. 556-559.

1885, December 1, Washington, D. C. [1] p. Wide 8°. Regarding publication of Register of Membership.

1886, January 1, [Washington, D. C.] [1] p. 8°. Notice to Inspectors, Deputies and Bodies.

1886, February 8, Washington, D. C. [1] p. folio. Regarding moneys due Supreme Council from Bodies of the Rite.

Same in Official Bulletins of Supreme Council, v. 7, p. 559-560.

1886, February 18, Washington, D. C. [2] p. Wide 8°. Scottish Rite in Japan, embodying a petition from members in Yokohama for a Grand Consistory there.

1886, February 19, Washington, D. C. [2] p. Wide 8°. Regarding granting of a petition for a Consistory in Fargo, N. Dakota, with copy of the petition.

1886, February 20, Washington, D. C. [1] p. Wide 8°. To the Inspectors and Deputies of the Supreme Council regarding the non-receipt of supplies ordered by Bodies of their jurisdiction.

1886, February 25, Washington, D. C. [1] p. Wide 8°. Notice of Secretary General's resignation and the appointment of Frederick Webber as such.

1886, March 9, Washington, D. C. [2] p. Wide 8°. Requesting answers to certain questions about rituals and other supplies.

1886, May 24, Washington, D. C. [2] p. Wide 8°. Letter to Juan M. Grau, Grand Commander of the Supreme Council of New Granada.

Same in Official Bulletins of Supreme Council, v. 8, p. 233-235.

1886, September 1, Washington, D. C. [2] p. Wide 8°. Notice of the approaching session of the Supreme Council, 1886.

1886, September 2, Washington, D. C. [1] p. Wide 8°. Requesting contributions for the sufferers from the earthquake at Charleston, S. C.

Same in his Official Bulletins, v. 8, p. 68-69.

1886, November 17, Washington, D. C. [4] p. Wide 8°. Regarding recognition of the Supreme Council of Dominican Republic.

Same in his Official Bulletins, v. 8, p. 142-147. *Same in same,* v. 10, p. 55-60.

1886, November 20, Washington, D. C. [2] p. Wide 8°. Appeal for Fund of Fraternal Assistance.

Same in his Official Bulletins, v. 8, p. 66-67.

1887, June 12, Washington, D. C. [1] p. Wide 8°. Notice of appointment of officers in the Supreme Council.

1887, September 15, Washington, D. C. [3] p. Wide 8°. Regarding his ''Beauties of Cerneauism,'' and comments on spurious Scottish Rite masonry.

Same in his Occasional Bulletins, No. 9, p. 3-7. Official Bulletins, v. 8, p. 335-339.

1887, October 1, Washington, D. C. [3] p. Wide 8°. Letter forwarding a communication, translated, from the Supreme Council of Belgium, regarding a conference of all Supreme Councils.

1888, May 1, Washington, D. C. [1] p. Wide 8°. Regarding conferring the degrees on subjects of the British Crown.

Same in his Official Bulletins, v. 8, p. 342-343.

1888, September 15, Washington, D. C. [1] p. Wide 8°. Notice of the meeting of the Supreme Council, 1888.

Same in his Official Bulletins, v. 9, p. 1-2.

1888, September 20, Washington, D. C. [1] p. Wide 8°. Appeal for yellow fever sufferers in Florida.

Same in his Official Bulletins, v. 9, p. 19-20.

1888, September 30, Washington, D. C. 9 p. 8°. Giving a list of the legitimate Supreme Councils and their officers.

1889, January 20, Washington, D. C. [1] p. Wide 8°. Regarding the circulation of a pamphlet and the recognition of the Supreme Council of the Dominican Republic.

Same in his Official Bulletins, v. 9, p. 20-21.

1889, June 3, Washington, D. C. [1] p. Wide 8°. Appeal for sufferers of the Johnstown, Penna., flood.

Same in his Official Bulletins, v. 9, p. 360-361.

1889, June 20, Washington, D. C. [1] p. Wide 8°. Regarding the holding of a convention of the Masonic Veterans of the United States.

1889, August 20, Washington, D. C. [2] p. Wide 8°. Regarding Cerneauism.

Same in his Occasional Bulletins, No. 10, p. 7-10. Official Bulletins, v. 9, p. 361-363. *Same in same,* v. 10, p. 11-13.

1889, December 20, Washington, D. C. [2] p. Wide 8°. Regarding the Supreme Council of Spain.

Same in his Official Bulletins, v. 10, p. 134-136.

1890, June 21, Washington, D. C. [1] p. Wide 8°. Regarding the Official Register of the Supreme Council.

1890, September 25, Washington, D. C. [1] p. Wide 8°. Notice to active members of the approaching session of the Supreme Council, 1890.

1890, September 25, Washington D. C. [1] p. Wide 8°. Notice to members of the approaching session of the Supreme Council.

1890, October 15, Washington, D. C. [1] p. Wide 8°. Requesting donations of indian arrow-heads for the Museum of the Supreme Council.

Same in his Occasional Bulletins, No. 11, p. 6.

CERNEAU CONTROVERSY.

An apology—so-called. [Washington, 1883.] 5 p. 8°. Caption title.
Signed: Albert Pike, 33d, Grand Commander.

Beauties of Cerneauism. No. 1. [By Albert Pike.] [Washington, 188—.] 4 p. 8°. Caption title.

Beauties of Cerneauism. No. 2. [By Albert Pike.] [Washington, about 1886.] 3 p. 8°. Caption title.

Beauties of Cerneauism. No. 3. [By Albert Pike.] [Washington, about 1887.] 15 p. 8°. Caption title.

Beauties of Cerneauism. No. 4. 7 p. 8°. Caption title.
Signed: Albert Pike, Washington, 23rd July, 1887.

Beauties of Cerneauism. No. 5. [Washington.] 50 p. 8°. Caption title.
Signed: Albert Pike, 33°, Grand Commander, August 1, 1887.

Beauties of Cerneauism. No. 5. Supplement. [Washington.] 6 p. 8°. Caption title.
Signed: Albert Pike, 33°, Grand Commander, September 15, 1887.

Beauties of Cerneauism. No. 5. Appendix: The record. [Washington, about 1887.] 14 p. 8°. Caption title.
Signed: Albert Pike, Grand Commander. These last three items are often bound together.

Beauties of Cerneauism. No. 6. [Washington.] 94 p. 8°. Caption title.
Signed: Albert Pike, Washington, August, 1887.

Beauties of Cerneauism. No. 6. Appendix. [Washington.] 5+15+1 p. 8°. Caption title.
Signed: Albert Pike, 33°, Grand Commander, September, 1887.

The ''Cerneau Supreme Council, so-called. A caution to Master Masons. Charleston, [Washington] 1881, 17 p. 8°.
Signed ‡ (that is, Albert Pike) April 10, 1881.

Cerneauism. Pertinent questions to be asked by it's victims. [Washington, about 1887.] 15 p. 8°. Caption title.
Signed ‡ (that is Albert Pike).

Chastisement of a bearer of false witness. Washington, August, 1889. With appendix. 24 p. +15+1 p. 8°.
Signed: Albert Pike, 33° :. Grand Commander, Washington, August 20, 1889.

A few more Cerneauisms. [Washington, 1885.] 12 p. 8°. Caption title.
Signed: Albert Pike, 33°, Grand Commander.

Foulhouzeism and Cerneauism scourged. Dissection of a manifesto. New York, press of J. J. Little & Co., 10 to 20 Astor Place, 1884. 116 p. 8°.
Signed: Albert Pike, 33d :. Grand Commander, 1st November, 1883.

Foulhouzeism and Cerneauism scourged. Dissention of a manifesto. New York, press of J. J. Little & Co., 10 to 20 Astor Place, 1889. 116 p. 8°.
Signed: Albert Pike, 33d :. Grand Commander, 1st November, 1883.

A fragrant nosegay of CCXXV flowers culled from the twin-parterres of Cerneauism. [By Albert Pike.] [Washington, 188—.] 47 p. 8°. Caption title.

Getting recognized rapidly. Cold comfort for dupes. 11 p. 8°.
Signed: Albert Pike, 33°, Grand Commander. Dated Washington, D. C., May 24, 1886.

A historical inquiry in regard to the Grand Constitutions of 1786, p. 125-211.

Preface signed: Albert Pike, 33° ∴ Grand Commander, Washington, 1st February, 1883.

Originally published in 1872 as an introduction to the Latin Constitutions of 1786, and retaining the same pagination.

History vs. Cerneauism. [Washington, 1885.] 22 p. 8°. Caption title.

Signed: ‡ (that is, Albert Pike).

The ignobility of Cerneauism exposed. Charleston, [Washington] September, 1889. 36 p. 8°.

Signed: Albert Pike, 33° ∴ Washington, September 12, 1889.

An inaccurate historian. [Washington,] 188—.] 8 p. 8°. Caption title.

Signed: ‡ Albert Pike, 33°.

Indictment and proof. 18 p. 8°.

Signed: Albert Pike, 33°, Grand Commander, Washington, August 10, 1889.
Same in Voice of Masonry, v. 27, no. 10, October, 1889, p. 922-934.

Latest Cerneauisms. [Washington, 188—.] 19 p. 8°. Caption title.

Signed: ‡ (that is, Albert Pike).

Masonic origines.]Washington, about 1885.] 16 p. 8°. Caption title.

Signed: ‡ (that is, Albert Pike).
Same in Texas Masonic Journal, v. 1, nos. 3-4, March and April, 1886, p. 79-82, 117-120.

Masonic origines. [Washington, about 1886.] 26 p. 8°. Caption title.

Signed: Albert Pike.

Masonic origines. By Albert Pike. Published by the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. Second edition. Washington, 1887. 24 p. 8°.

The modern Caliban. [Washington.] 9 p. 8°. Caption title.

Signed: ‡ (that is, Albert Pike) 1st February, 1886.

Of Cerneauism. A memoir on the part of the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. New York, press of J. J. Little & Co., 10 to 20 Astor Place, 1884, 79 p. 8°.

Signed: Albert Pike, 33°, Grand Commander [etc.], Washington, 1st January, 1884.

Of Cerneauism. Supplement. [By Albert Pike.] [N. p. N. d.] 47 p. 8°.

The above two pamphlets are usually bound together.

Pertinent questions for impostors to answer: suggested to their dupes. From letters of the Grand Commander [Albert Pike] of the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. 17 p. 8°. Caption title.

Dated at Washington, 1884.

Pertinent questions to be asked by the victims of the twin bastards of Cerneauism. 16 p. 8°. Caption title.

Signed: Albert Pike, 33° ∴ Grand Commander of the Supreme Council for the Southern Jurisdiction of the United States, Washington, 15th November, 1887.

A slight contribution to the history of Cerneauism. [Washington, about 1885.] 16 p. 8°. Caption title.

Signed: ‡ (that is, Albert Pike).

Squirmings. [By Albert Pike.] [Washington, about 1889.] 15 p. 8°. Caption title.

The Sup[reme] Council for France and it's dependencies. *In re* Joseph Cerneau. [With notes by Albert Pike.] Or]ient[of Washington, 1886. 72 p. 8°.

Another edition having after the imprint: "Distributed by the Supreme Council for the Northern Masonic Jurisdiction."

RITUALISTIC AND CEREMONIAL.

Ceremonial of a Lodge of Sorrow. [By Albert Pike.] [N. p. N. d.] 18 p. 12°. Caption title

Ceremonial of a Lodge of Sorrow, [By Albert Pike] held in memory of a Sovereign Grand Inspector General, deceased, as used on the 30th of March, 1860, for Ill∴ Bro∴ John Anthony Quitman, 33d, by the Supreme Council for the Southern Jurisdiction of the United States. New Work, Macoy & Sickels, 430 Brooms street, 1860. 15 p. 8°.

Same in Supreme Council Southern Jurisdiction, Transactions, 1869, p. 65-76.

Ceremonial of masonic baptism [By Albert Pike] in the Ancient and Accepted Scottish Rite of freemasonry. Charleston and New York, Edmund Jones & Co., printers and stationers, No. 26 John street, 1865. 42 p. 8°.

Ceremonies at the obsequies of a Knight Kadosh. [Washington? 1879.] 13 p. Wide 8°.

Signed: Albert Pike.
Same Officia supreme at the obsequies of a Knight Kadosh. Or[ient] of Charleston [Washington], 1887. 18 p. Wide 8°.

Ceremonies of extinguishing and relighting the lights. [By Albert Pike.] Alternative. To be used by any chapter at its option, if preferred by it to the ceremonies heretofore observed. [Washington? 1885?] 15 p. 8°.

Funeral ceremony and ceremony of a Lodge of Sorrow of the Ancient and Accepted Scottish Rite of Freemasonry. [By Albert Pike.] Southern Jurisdiction of the United States of America. Charleston, S. C., 1868. 2 plates. 95 p. 8°.

Funeral ceremony of the Ancient and Accepted Scottish Rite of Freemasonry. [By Albert Pike.] Southern Jurisdiction of the United States of America. Honolulu [Hawaii]. H. L. Sheldon, printer, 1877. 38 p. 8°.

Funeral ceremony and offices of a Lodge of Sorrow of the Ancient and Accepted Scottish Rite of Freemasonry. [By Albert Pike.] Southern Jurisdiction of the United States of America. Or[ient] of Charleston [New York or Washington.] 5646 [1886.] Illus. 83 p. 8°.

Latter day rituals. *In* Brownell, J. H. Gems from the quarry, v. 2, p. 467.

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction of the United States. [By Albert Pike.] Part I. I-III. Charleston, [New York, J. J. Little & Co., printers, 10 to 20 Astor Place.] A∴M∴ 5638 [1878.] 223 p. 8°.

Rubicated title page. Colored plates and illustrations.

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry for the Southern Jurisdiction of the United States. [By Albert Pike.] Part II. IV to XIV. Charleston [New York, Masonic Publishing and Manufacturing Co.] A∴M∴ 5627, [1867.] 240 p. 8°.

Rubicated title page. Colored plates and illustrations.

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry for the Southern Jurisdiction of the United States. [By Albert Pike.] Part II. IV to XIV. Charleston, A∴M∴ 5638 [1878.] New York, press of J. J. Little & Co. 243 p. 8°.

Rubricated title page. Colored plates and illustrations. Copyright, 1877.

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction of the United States. [By Albert Pike.] Part II. IV to XIV. Charleston A∴M∴. 5638 [1878.] New York, press of J. J. Little & Co., 10 to 20 Astor Place. 243 p. 8°.

Rubricated title page. Colored plates and illustrations. Copyright, 1877.

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction of the United States. [By Albert Pike.] Part II. IV to XIV. Charleston, A∴M∴. 5638, [1878.] New York, Robert Macoy, 4 Barclay street. 243 p. 8°.

Rubricated title page. Colored plates and illustrations. Copyright, 1877. Copyright page says: "New York, J. J. Little & Co., printers, 10 to 20 Astor place."

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction of the United States. [By Albert Pike.] Part III. XV to XVIII. Charleston, A∴M∴, [1878.] New York, Robert Macoy, 4 Barclay street. 187 p. 8°.

Rubricated title page. Colored plates and illustrations. Copyright, 1877. Copyright page says: "New York, J. J. Little & Co., printers, 10 to 20 Astor place."

Liturgy of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdoction of the United States. [By Albert Pike.] Part IV. XIX to XXX. Charleston,]New York, J. J. Little & Co., printers, 10 to 20 Astor Place.] A. M. 5638, [1878.] 291+2 p. 8°.

Rubricated title page. Colored plates and illustrations.

[The Magnum Opus. By Albert Pike.] [New Orleans? 1858.] [604 p.] 4°.

No title page. The work is known as the "Magnum Opus," or great work. Only 100 copies printed. Each degree, from the 4th to the 32nd inclusive is paged separately. The esoteric work and lectures of the rituals of the Scottish Rite.

Morals and Dogma of the Ancient and Accepted Scottish Rite of Freemasonry. Prepared [By Albert Pike] for the Supreme Council of the Thirty-Third Degree, for the Southern Jurisdiction of the United States, and published by its authority. Charleston, [New York, Masonic Publishing Co., 626 Broadway.] A∴M∴. 5632, [1872.] 861 p. 8°.

Rubricated title page.

Morals and Dogma of the Ancient and Accepted Scottish Rite of Freemasonry. Prepared [By Albert Pike] for the Supreme Council of the Thirty-Third Degree, for the Southern Jurisdiction of the United States, and published by its authority. New York, Robert Macoy, 4 Barclay street, 1878. 861 p. 8°.

Rubricated title page.

Morals and Dogma of the Ancient and Accepted Scottish Rite of Freemasonry Prepared [By Albert Pike] for the Supreme Council of the Thirty-Third Degree, for the Southern Jurisdiction of the United States, and published by its authority. Charleston, [New York?] A∴M∴. 5641, [1881.] 861 p. 8°.

Some copies of this edition were divided into four parts and bound in paper covers, separate ttle pages to each part, the first: Lodge of perfection; second: Chapter of Rose Croix; third: Council of Kadosh; fourth: Consistory. Rubricated title pages.

Morals and Dogma of the Ancient and Accepted Scottish Rite of Freemasonry Prepared [By Albert Pike] for the Supreme Council of the Thirty-Third Degree, for the Southern Jurisdiction of the United States, and published by its authority. Charleston, [Washington, George E. Howard & Co.] A∴M∴. 5641, [1881.] [Copyright, 1905.] 861 p. 8°.

Rubricated title page.

Morals and Dogma of the Ancient and Accepted Scottish Rite of Freemasonry Prepared [By Albert Pike] for the Supreme Council of the Thirty-Third Degree, for the Southern Jurisdiction of the United States, and published by its authority. Charleston, [Manufactured by L. H. Jenkins, Inc., Richmond, Va., May, 1918.] A∴M∴ 5641, [1881.] 861 p. 8°.

Rubricated title. The above editions of this work are printed from stereotyped plates.

Offices of consecration and dedication of a temple or hall of the Ancient and Accepted Scottish Rite of Freemasonry in the Southern Jurisdiction, U. S. A. [By Albert Pike.] Gr[and] Or[ient] of Charleston, 1886. 26 p. 8°.

Propably printed in Washington.

Offices of consecration and dedication of the House of the Temple of the Supreme Council of the 33d degree of the Ancient and Accepted Scottish Rite of Freemasonry, for the Southern Jurisdiction, U. S. A. [By Albert Pike.] At the orient of Washington, October 22, 1884. 23 p. 8°.

Offices of consecration of a hall of freemasons of the Ancient and Accepted Scottish Rite in the Southern Jurisdiction of the United States. [By Albert Pike.] Or[ient] of Charleston, A∴M∴ 5635. Washington, D. C., printed by Judd & Detweiler, 1875. 16 p. 8°.

Office of constitution and inauguration of a Lodge of Perfection, and installation of its officers, [By Albert Pike] as used in the Southern Jurisdiction of the United States. 'lepodoy. [New York?] A∴M∴ 5630, [1870.] 92 p. 8°.

Copyright 1872. There are two title pages. The first one reads: "Offices of inauguration and installation of the Ancient and Accepted Scottish Rite, as used in the Southern Jurisdiction of the United States. A∴M∴ 5630."

Offices of constitution and inauguration of a Lodge of Perfection, and installation of its officers, [By Albert Pike] as used in the Southern Jurisdiction of the United States. New edition. Or[ient] of Charleston [New York.] 5643 [1883.] 78 p. 8°.

Offices of constitution and inauguration of a Council of Princes of Jerusalem, and installation of its dignitaries and officers, [By Albert Pike] as used in the Southern Jurisdiction of the United States. 'lepodoy. [New York?] A∴M∴ 5630 [1870.] 86 p. 2 plates. 8°.

Copyright 1872.

Offices of constitution and inauguration of a Chapter of Knights Rose Croix of Hierodom, and installation of its dignitaries and officers, [By Albert Pike] as used in the Southern Jurisdiction of the United States. 'lepodoy. [New York?] A∴M∴ 5630 [1870.] 60 p. 2 plates. 8°.

Offices of constitution and inauguration of a Council of Knights Kadosh, and installation of its officers, [By Albert Pike] as used in the Southern Jurisdiction of the United States. 'lepodoy. [New York?] [about 1870.] 87 p. 3 plates. 8°.

Offices of constitution and inauguration of a Consistory of the 32d degree. [By Albert Pike.] [N. p. N. d.] 76 p. 8°.

Offices of masonic baptism, Reception of a Louveteau, and Adoption. Prepared [By Albert Pike] for the Supreme Council, 33°, for the Southern Jurisdiction of the United States. 'lepodoy. [New York?] A∴M∴ 5631 [1871.] Illus. 70+70+74 p. 8°.

Officia supreme at the obsequies of a Knight Kadosh.
See Ceremonies at the obsequies of a Knight Kadosh.

[Hebrew text.] The porch and the middle chamber. . . The book of the lodge [by Albert Pike.] 'Iepodoy. [New York?] A∴M∴ 5632 [1872.] 343 p. 8°. Illus.
Rubricated title page.

[Hebrew Text] or, The inner sanctuary. [By Albert Pike.] Part First. The book of the Lodge of Perfection. Latomopolis [New York?] A∴M∴ 5621 [1861.] 280 p. 8°.
Rubricated title page.

The inner sanctuary. [By Albert Pike.] Part 1. The book of the Lodge of Perfection. 'Iepodoy. [New York?] A∴M∴ 5630 [1870.] 315 p. 8°.
Rubricated title page.

The inner sanctuary. [By Albert Pike.] Part I. The book of the Lodge of Perfection. Or[ient] of Charleston [New York?] A∴M∴ 5643 [1883.] 290 p. 8°.
Rubricated title page.

Der innere tempel. [By Albert Pike.] Erster theil. Das buch der Loge der Vollkommenheit. 'Iepodoy. [New York?] A∴M∴ 5630 [1870.] 242 p. 8°.

[Geheime Arbeit. IV-XIV. By Albert Pike.] 38 p. 8°.
Title taken from bound cover. N. p. N. d.
Rubricated title page.

The inner sanctuary. [By Albert Pike.] Part II. The book of the second temple. [New York?] A∴M∴ 5630 [1870.] 109 p. 8°.

[Hebrew text] or The inner sanctuary [by Albert Pike.] Part III. Latomopolis [New York?] A∴M∴ 5621 [1861.] 144 p. 8°.
Rubricated title page.

[Hebrew text] or The inner sanctuary [by Albert Pike.] Part III. [New York?] A∴M∴ 5630 [1870.] 154 p. 8°.
Rubricated title page.

The inner sanctuary. [By Albert Pike.] Part IV. The book of the Holy House. [New York?] A∴M∴ 5627 [1867.] 553 p. 8°.
Rubricated title page.

The inner sanctuary. [By Albert Pike.] Part IV. The book of the Holy House. [New York?] A∴M∴ 5644 [1884.] 487 p. 8°.

The inner sanctuary. [By Albert Pike.] Part V. The book of the Holy House. [New York?] A∴M∴ 5627 [1867.] 296 p. 8°.
Rubricated title page.

Ritual. [By Albert Pike.] Part V. The inner sanctuary. The book of the great Light. [New York, J. J. Little & Co., 10 to 20 Astor Place.] A∴M∴ 5639 [1879.] 141 p. 8°.
Colored plates and illustrations.

[Twenty-fifth Degree:]

I°. Book. House of the Earth. 8 p.

II°. Book. House of the Planets. 8 p.

III°. Book. House of the Sun and Moon. 5 p.

IV°. Book. House of the Light. 5 p.

All by Albert Pike. Wide 8°, N. p. N. d. Cover titles.

Ancient and Accepted Scottish Rite. Thirty-first and thirty-second degrees. By Ill∴ Bros. Albert Pike, 33d and Charles Laffon DeLadebat, 33d, Active members of the Supreme Council for the Southern Jurisdiction of the United States of America, sitting at Charleston, S. C. New Orleans, 1858. 48+68 p. 8°.

[Esoteric work of the 1-3°, according to the Ancient and Accepted Scottish Rite. By Albert Pike.] N. p. N. d. 16 p. 12°.

[Esoteric work of the 1-3°, according to the Ancient and Accepted Scottish Rite. By Albert Pike.] N. p. N. d. 43 p. 4°.

[Esoteric work of the IV-XIV]. By Albert Pike. Washington?] N. d. 36+2 p. 8°.

[Esoteric work of the IV-XIV°. By Albert Pike.] Supreme Council Press, 1909. 36 p. 8°.

[Esoteric work of the XV-XVIII°. By Albert Pike. Washington?] N. d. 45+ 2 p. 8°.

[Esoteric work of the XV-XVIII°. By Albert Pike.] Supreme Council Press, A∴M∴ 5665 [1905] 45 p. 8°.

[The esoteric work of the XIX-XXX°. By Albert Pike. Washington?] N. d. 28+2 p. 8°.

[The esoteric work of the XIX-XXX°. By Albert Pike. Supreme Council Press, A∴M∴ 5667 (1907)] 28 p. 8°.

[The esoteric work of the XXXI-XXXII°. By Albert Pike. Washington? about 1879.] 24+3 p. 8°.

[The esoteric work of the XXXI-XXXII°. By Albert Pike. Washington, Supreme Council Press, A∴ M∴ 5667 (1907)]. 24 p. 8°.

Legenda of the Lodge of Perfection, Southern Jurisdiction, U. S. A. [By Albert Pike.] Charleston, [Washington?] 1888. 43 p. 8°.

Same. N. p. 1921. 43 p. 8°.

Legenda. [By Albert Pike.] XIX-XXX°. [N. p. N. d.] 170 p. 8°.

XXXII°. Legenda [A] [By Albert Pike.] [N. d., about 1883.]. 42 p. 8°.

XXXII°. Legenda B. [By Albert Pike.] [N. p. N. d.] 23 p. 8°.

XXXII°. Legenda [A]-B. [By Albert Pike.] [N. p. N. d.] 42+23 p. 8°.

Readings. XXXII°. [By Albert Pike.] [N. p. N. d.] 162 p. 8°.

See also manuscripts.

MISCELLANEOUS.

Albert Pike on blue lodge masonry. *In* Trestle Board, v. 17, no. 8, February, 1904, p. 296.

Albert Pike on prayer. *In* Trestle Board, v. 15, no. 2, August, 1901.

Ancient and Accepted Scottish Rite of Freemasonry. The constitutions and regulations of 1762. Statutes and regulations of Perfection and other degrees. Vera instituta secreta et fundamenta ordinis of 1786. The secret constitutions of the 33d degree, with the statutes of 1859, 1866, 1868, 1870 and 1872, of the Supreme Council for the Southern Jurisdiction. Compiled by Albert Pike, Sovereign Grand Commander of the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. New York, Masonic Publishing Company, No. 626 Broadway, A. M. 5632. [1872] 467 p. 4°.

Same. 8°.
Rubricated title pages to both above editions.

Ancient and Accepted Scottish Rite of Freemasonry. The constitutions and regulations of 1762. Statutes and regulations of Perfection, and other degrees. Vera instituta secreta et fundamenta ordinis of 1786. The secret constitutions of the 33d degree, with the statutes of 1859, 1866, 1868, 1870, and 1872, of the Supreme Council for the Southern Jurisdiction. Compiled by Albert Pike, Sovereign Grand Commander of the Supreme Council of the 33d degree for the Southern Jurisdiction of the United States. New York, Masonic Publishing Company, A. M. 5632. [1872] New edition printed by J. J. Little & Co., 5664. [1904] 508 p. 8°.

Rubricated title page.
The Latin constitutions of 1786. Re-translated from the Latin. *In* New Age Mazazine, v. 5, no. 3, Sept., 1906, p. 273-279.

Baal and Aun. *See* Holy (The) Triad.

Balustre of the Sovereign Grand Commander [Albert Pike] on certain foreign relations. *In* Supreme Council, Southern Jurisdiction, Transactions, 1868, p. 147-188.

The book of the words. [Sephar h'debarim.] [N. p.] A∴M∴ 5638. [1878.] 176+4 p., Wide 8°.

150 copies only printed.

Gouley, George Frank. Charges and specifications against. *In* Supreme Council, Southern Jurisdiction, Transactions, 1868, p. 69-74.

The Christian mysteries. *In* Brownell, J. H. Gems from the quarry, v. 2, p. 151-152.

Decisions on masonic law regulating rejections for membership in the fraternity. By Albert Pike. *In* New Age Magazine, v. 10, no. 1, January, 1908, p. 92-96.

The decisions of the Supreme Council [etc.] *See* The Supreme Council, 33d degree and the blue degrees.

Degrees are lessons. *In* Voice of Masonry, v. 27, no. 8, August, 1889, p. 700-702.

The duties of freemasonry. *In* Trestle Board, v. 8, no. 4, April, 1894, p. 145-151.

Fate and change. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 423.

Fellowship, *In* Brownell, J. H. Gems from the quarry, v. 1, p. 434; v. 2, p. 433-434.

Freemasonry [Meaning of.] *In* Voice of Masonry, v. 22, no. 3, March, 1884, p. 192-195.

Freemasonry has its faults. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 434.

Freemasonry is tolerance. *In* Square & Compass, v. 4, no. 3, May, 1895, p. 61-63.

Gnosticism, the Kabbala, and the mysteries, as connected with and illustrating masonry. Nos. 1-5. *In* American Quarterly Review of Freemasonry, v. 1, p. 14-38, 160-191, 368-407, 448-460; v. 2, p. 19-33, 162-178, 313-335, 448-467.

Gorgas, Ferdinand, J. S., Chairman of Committee of Foreign Correspondence vs. The Grand Orient of France and the union of Germanic Grand Lodges. [Washington, 188—.] 8 p. 8°.

Signed: ‡ (that is, Albert Pike).

A great brotherhood. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 189.

Great ideas in mysteries. *In* Voice of Masonry, v. 35, no. XI, November, 1897, p. 803-825.

The holy triad . . Jah: Baal-Peor, the Syrian priapus: the city of idalotry and iniquity. A reply to the Grand Chaplain and Grand High Priest of the Grand Royal Arch Chapter of Massachusetts. (From Mackey's National Freemason.) Washington City, office of Mackey's National Freemason, 1873. 34 p. 8°.

Signed: Albert Pike.
Same, entitled "Baal and Aun." *In* Mackey's National Freemason, v. 2, Sep., 1873, p. 626-657.

Humanity. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 37-.

Individual responsibility. *In* Brownell, J. H. Gems from the quarry, v. 2, p. 468.

Lecture on masonic symbolism. [By Albert Pike.] Gloria dei est celare verbum. [New York? about 1875.] Illus. 188 p. 4°.

Probably printed by Lange, Little & Co., who printed his "Second lecture." 100 copies only printed and distributed to 32nds or 33rds, who had contributed towards the expense of its publication, and Pike enjoined "That this volume shall never be sold or otherwise disposed of."

A second lecture on symbolism. The Omkara and other ineffable words. [By Albert Pike.] [New York, Lang, Little & Co., printers,]about 1876.] Illus. 292 p. 4°.

100 copies only printed. Intended as the complement of his "Lecture on masonic symbolism.

A letter touching masonic symbolism. 10 p. 8°. Caption title.

Signed: Albert Pike, Washington, 8th November, 1889.
The letter is to Robert Freke Gould, the celebrated masonic historian of England.
Same in his Official Bulletins, v. 10, p. 306-312.

Life. *In* Bromwell. J. H. Gems from the quarry, v. 1, p. 302.

Light against darkness. *In* Bromwell, J. H. Gems from the quarry, v. 2, p. 238.

Livery companies or guilds. *In* Mackey's National Freemason, v. 1, April, 1872, p. 339-352.

Masonic (The) and patriotic feast to Bro. the Gen. Lafayette, Sov. G. Insp. G. 33d Deg., by the lodges of the French and Scottish Rites, united, October 10, 1830. Translated from the French for the American Freemason, by M. W. Bro. Albert Pike, of Arkansas. *In* American Freemason of Louisville, Ky., v. 3, nos. 5-8, December, 1854, January, 1855, p. 34, 42, 50, 58.

Masonic gems. *In* Voice of Masonry, v. 19, no. 3, March, 1881, p. 196-198.

Masonic justice. *In* Trestle Board, v. 7, no. 6, June, 1893, p. 245-250.

Masonic trials. *In* New Age Magazine, v. 9, no. 6, December, 1908, p. 575-580. From decisions in Supreme Council Transactions of 1880, p. 28.

Masonic views of christianity. *In* American Freemasons Magazine, v. 5, January 9, 1860, p. 43-45.

Masonry (The) of Adoption. [By Albert Pike.] N. p. [1866] [234] p.

Same. [Extracts] *In* Masonic Eclectic (New York), v. 3, no. 1, November, 1867, p. 332-338.

Materials for the history of freemasonry in France and elsewhere on the continent of Europe, from 1718 to 1859. By Albert Pike, 33° . . v. 1, A∴M∴ 5636, [1876.] 78 p. 8°.

The beginning of this work, which was to be published from time to time in his Official Bulletins, the "Vol. 1," being additional pages 1-78 of his Official Bulletins, v. 3, no. 2, July, 1876.

See also his Manuscripts.

Materials for the history of freemasonry in France. [By Albert Pike.] Edited, arranged and annotated by George F. Moore. *In* New Age Magazine, v. 1, no. 6, December, 1904, p. 577-594; v. 2, nos. 1, 2, 4, 5, January, February, April, May, 1905, p. 61-73, 165-177, 347-360, 429-438; v. 3, nos. 1-6, July-December, 1905, p. 55-66, 157-165, 251-261, 349-355, 449-457, 549-556; v. 4, nos. 1-6; January-June, 1906, p. 49-58, 149-157, 249-257, 349-357, 449-456, 549-555; v. 5, nos. 1-6, July-December, 1906, p. 49-56, 145-152, 241-244, 335-340, 433-439, 531-539; v. 6, nos. 1-6, January-June, 1907, p. 49-55, 147-152, 245-250, 343-348, 441-447, 539-545; v. 7, nos. 1-3, 5, 6, July-September, November, December, 1907, p. 49-55, 147-153, 243-249, 435-441, 531-535; v. 8, nos. 1-6, January-June, 1908, p. 49-56, 145-150, 251-254, 347-353, 441-445, 537-542; v. 9, nos. 1-4, July-October, 1908, p. 49-54, 144-148, 241-244, 341-345; v. 10, no. 6, June, 1909, p. 540-543; v. 11, nos. 1-4, July-October, 1909, p. 55-58, 145-149, 272-276, 337-341.

Embodying about all of v. 1 of his Manuscripts on the subject.

Necessity of study to a mason. *In* Masonic Eclectic (New York), v. 1, no. 1, September, 1860, p. 33-34.

The nine great truths in masonry. *In* American Quarterly Review of Freemasonry, v. 1, p. 80-85; Voice of Masonry, v. 27, no. 3, March, 1889, p. 202-207.

Occasional Bulletins of the Supreme Council for the Southern Jurisdiction of the United States. [Compiled and edited by Albert Pike.]

No. 1, December, 1887. [Washington.] 3 p. 8°.

No. 2, March, 1888. [Washington.] 17 p. 8°.

Another edition: No. 2, March, 1888. [Washington.] 31 p. 8°. P. 17-31 of this edition contain the same subject matter as the first copy.

No. 3, April, 1888. 9 p. 8°.

No. 4, May, 1888. 12 p. 8°.

No. 5, June, 1888. 48 p. 8°.

No. 6, July, 1888. 48 p. 8°.

No. 7, September, 1888. 33 p. 8°.

No. 8, April, 1889. 56 p. 8°.

No. 9, July, 1889. 9 p. 8°.

Supplement, July, 1889. 8 p. 8°.

No. 10, January, 1890. 113 p. 8°.

No. 11, March, 1891. 61 p. 8°.

No. 12, May, 1891. 101 p. 8°.

These Bulletins were all probably printed in Washington. No. 12 appeared after Pike's death in April, 1891.

Official Bulletins of the Supreme Council of the 33rd degree for the Southern Jurisdiction of the United States. [Compiled and edited by Albert Pike.]

Vol. 1, no. 1, May, 1870. Charleston. [Masonic Publishing Co., 432 Broome street, New York.] p. 1-56 8°. Some copies of this number are printed: "For the Southern and Northern Jurisdiction," and contain the imprint: "Charleston and Boston."

No. 2, August, 1870. Charleston [Masonic Publishing Co., New York.] p. 57-138 8°.

No. 3, April, 1871. Charleston [Masonic Publishing Co., New York.] p. 139-326 8°.

No. 4, December, 1871. Charleston [Masonic Publishing Co., 626 Broadway, New York.] p. 327-548 8°.

No. 5, June, 1872. Charleston [Masonic Publishing Co., 626 Broadway, New York.] p. 549-660.

Vol. 2, No. 1, August, 1872. Charleston [Union Printing Co., 79 John street, New York.] 218 p. 8°.

No. 2, April, 1873. Charleston [Union Printing Co., 79 John street, New York.] 244 p. 8°. Cover title "June, 1873," as date.

No. 3, August, 1874. Charleston [Masonic Publishing Co., 626 Broadway, New York.] 205 p. 8°. Cover title says "Jenuary, 1875."

Vol. 3, No. 1, January, 1875. Charleston [New York. Lange, Little & Co., printers, No. 10 to 20 Astor Place.] p. 1-320 8°.

No. 2, July, 1876. Charleston [New York. Lange, Little & Co., printers, No. 10 to 20 Astor Place.] p. 321-350 8°. Additional pages 1-78, containing "Materials for the history of freemasonry in France and elsewhere on the continent of Europe, from 1718 to 1859. By Albert Pike, 33° [etc.] Nos. 1 and 2 were issued at the same time, in the same wrapper or covers.

No. [3], March, 1878. Gr[and] Orient of Charleston [New York. J. J. Little & Co., printers, 10 to 20 Astor Place.] p. 351-686 8°. Called "No. 2", should be "No. 3." Cover title says "April, 1878."

Vol. 4, No. 1, January 1, 1880. Charleston [New York?] p. 1-392 8°. Cover title says "April, 1880."

Nos. 2, 3, February, 1881, Charleston [New York?] p. 393-738, index p. 1-7, books p. 1-3.

Vol. 5, No. 1, July, 1882. Charleston. p. 1-415 8°.

No. 2, September, 1883. Charleston. p. 416-653, index 24 p. Cover title says "October, 1883."

Vol. 6, No. 1, April, 1884. Gr[and] Or[ient] of Charleston. p. 1-535 8°. Cover title says, "May, 1884."

No. 2, July, 1884, Gr[and] Or[ient] of Charleston, p. 536-651. Index 18 p. 8°.

Vol. 7, No. 1, April, 1885. Gr[and] Or[ient] of Charleston, p. 1-519. 8°. Cover title says "July, 1885."

No. 2, March, 1886. Gr[and] Or[ient] of Charleston, p. 520-824, index 20 p. Cover title says ''June, 1886.''

Vol. 8, No. 1, September, 1887. Gr[and] Or[ient] of Charleston, p. 1-332, supplemental pages 1-54, containing Allocution of the Grand Commander, session of 1886.

No. 2, September, 1888. Gr[and] Or[ient] of Charleston, p. 333-748, index 21 p. 8°. Cover title says ''October, 1888.''

Vol. 9, No. 1, March, 1889. Gr[and] Or[ient] of Charleston, p. 1-339 8°. Cover title says ''April, 1889.''

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A plea for arbitration. *In* Brownell, J. H. Gems from the quarry, v. 1, p. 335-336; Voice of Masonry, v. 27, no. 4, April, 1889, p. 308-310.

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Signed: Albert Pike, Washington, 26th September, 1889.
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The first edition.

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Pages 49-59 of this edition contain extracts from "Profession of faith of the XIXth century," by Eugene Pelletan.

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P. 1-42 contain the original text and translation of the "Letter." P. 57-70 contain extracts from "Profession of faith of the XIXth century," by Eugene Pelletan.

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Signed: Albert Pike.

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Zoroaster or Zarathustra, and his doctrines. *In* Mackey's National Freemason, v. 3, December, 1893, p. 117-122.

$$= \frac{r^2 y_0}{\sin\beta + \sin\alpha} (\sin\alpha\sin\beta - \tfrac{1}{2}\cos^2\alpha - \alpha\sin\beta\cos\beta$$
$$+ \cos\alpha\cos\beta + \sin^2\beta - \tfrac{1}{2}\cos^2\beta - \beta\sin\beta\cos\beta).$$

Likewise for the integral of the second member between α and $+\beta$ we have

$$\frac{r^2 y_0}{\sin\beta - \sin\alpha}\int_{\alpha}^{\beta}(\sin\beta\cos\theta - \sin\theta\cos\theta - \sin\beta\cos\beta + \cos\beta\sin\theta)\,d\theta$$
$$= \frac{r^2 y_0}{\sin\beta - \sin\alpha} (\sin^2\beta - \tfrac{1}{2}\cos^2\beta - \beta\sin\beta\cos\beta - \sin\alpha\sin\beta$$
$$- \tfrac{1}{2}\cos^2\alpha + \alpha\sin\beta\cos\beta + \cos\alpha\cos\beta).$$

These two quantities are to be reduced to a common denominator, added together and equated with the first member (a.). Upon making simple cancellations, dividing through by $\sin\beta$, and factoring, we get the form of y_0 given in the last section.

85. Formula for H; Value of Ordinates. — When the value, of y_0 is computed, we can readily draw the stress diagram of Fig. 21, and scale the value of H; or the formula proved before, § 40, may be applied here, and is easily converted into the third form,

$$H = \frac{W}{y_0} \cdot \frac{c^2 - b^2}{2c} = W\frac{AK \cdot KB}{CK \cdot AB} = \frac{r(\sin^2\beta - \sin^2\alpha)}{y_0 \cdot 2\sin\beta} W. \quad (1.)$$

If calculations have already been made for y_0, the quantities desired for this formula are at hand.

Then the ordinate at each point of division, by which H is to be multiplied to give M for that point, will be, from § 84, if θ is the angle between the two radii from the crown and the point E,

$$EF = DF - DE = y_0\frac{\sin\beta \pm \sin\theta}{\sin\beta \pm \sin\alpha} - r(\cos\theta - \cos\beta). \quad (2.)$$

The plus sign is to be used for points between the weight and the farther abutment, and the minus sign between the weight and the nearer abutment. We must remember, however, that, if θ is measured from the crown to the right as the positive direction, all angles θ on the left of the crown will be negative, and their *sines* will be minus. If E F is plus, it gives a positive bending moment, tending to make the arch less convex, and *vice versa*.

86. Numerical Computation of M. — In any practical case *we should much prefer*, as more easy and sufficiently accurate, *to scale all of these quantities from a good-sized diagram;* but it may be well to compute one set

of values of M as an example, for fear the signs may give some readers trouble. Taking the case of Fig. 22, let $\beta = 45^\circ$ and $\alpha = 20^\circ$. Then the arc $\beta = .7854$ and $\alpha = .3491$; $\sin\beta = \cos\beta = .7071$; $\sin\alpha = .3420$, $\cos\alpha = .9397$. These values, substituted in the equation of § 83, give

$$y_0 = r\,\frac{(.5 - .1170)\left(.7854\,\dfrac{2}{.7071} - 2.1213\right)}{.5 - .1170 + 1.4142\,(.1194 + .9397 - .5554 - .7071)} = \frac{.0384}{.0954}\,r = .403\,r;$$

(1.), § 85, will then become

$$\mathrm{H} = \frac{(.5 - .1170)\,r}{1.4142 \times .403\,r}\,\mathrm{W} = \frac{.383}{.570}\,\mathrm{W} = .672\,\mathrm{W}.$$

$$\mathrm{Sin}\,\beta + \sin\alpha = 1.0491;\ \sin\beta - \sin\alpha = .3651;$$

$$\frac{y_0}{\sin\beta + \sin\alpha} = \frac{.403\,r}{1.0491} = .384\,r;\ \frac{y_0}{\sin\beta - \sin\alpha} = \frac{.403\,r}{.3651} = 1.104\,r.$$

VALUES OF M.

							W.			
θ	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	
$\sin\beta =$	.7071								.7071	$\sin\beta$
$+ \sin\theta$	$-.6428$	$-.5$	$-.3420$	$-.1736$	0	$+.1736$	$+.3420$	.5	.6428	$- \sin\theta$
Mult. by	.0643	.2071	.3651	.5335	.7071	.8807	1.0491	.2071	.0643	Mult. by
.384 =	.0247	.0795	.1402	.2049	.2715	.3382	.4029	.2286	.0710	1.104 =
$- \cos\theta$	.7660	.8660	.9397	.9848	1.0	.9848	.9397	.8660	.7660	$- \cos\theta$
	$-.7413$	$-.7865$	$-.7995$	$-.7799$	$-.7285$	$-.6466$	$-.5368$	$-.6374$	$-.6950$	
$+ \cos\beta$	.7071								.7071	$+ \cos\beta$
	$-.0342$	$-.0794$	$-.0924$	$-.0728$	$-.0214$	$+.0605$	$+.1703$	$+.0697$	$+.0121$	
$\times .672\,\mathrm{W}$	$-.0230$	$-.0534$	$-.0621$	$-.0489$	$-.0144$	$+.0407$	$+.1144$	$+.0468$	$+.0081$	$r\,\mathrm{W} = \mathrm{M}$

87. **Shear at any Right Section.** — Suppose that the rib of Fig. 22 carries a single weight under the point C, and that the curve of equilibrium is A C B. If 012 is the stress diagram, 2–3 will be the vertical component of the reaction at A, and 3–1 that at B. To find the shear on a right section near A, as at E, lay off 2–3, or P_1 in Fig. 23, and draw H so that the arrows may follow one another; then from 0 draw a line 0–4 parallel to the tangent at E; the perpendicular distance 4–2 will be the

shear in the web. For we see by the direction of the arrows that these forces last drawn balance P_1 and H, and, as in Fig. 18, no matter how much the bending moment, and hence the flange stress, may be, the perpendicular distance 4–2 is unchanged. The line 0–4 will be the magnitude of the direct thrust. Both of these forces are given on the right of the section, and this shear is therefore negative. In the same way, for the point E near B, draw 1–3 $= -P_2$ and 3–0 $=$ H; draw 0–8 parallel to the tangent at E; 8–1, perpendicular to it, will be the shear on the right of the section, again negative, and 0–8 will be the direct thrust. It is noticeable that the normal shear in the web near the left abutment is opposite in sign to P_1, while near the right abutment it agrees in sign with P_2. For the kind of brace needed, see Fig. 10. It is evident that these figures may at once be drawn on the stress diagram, where 0–4 and 4–2 are already sketched. Such a way will answer well for a few points on a large figure, especially if we have applied such loads as give the maximum shear at any particular point. If, however, we desire to see the variation of the shear across the span, we may draw a different diagram.

88. **Shear Diagram.** — As the tangent is perpendicular to the radius at the point of contact, we may at once see that the angles marked θ in Fig. 23 correspond with the angle θ made by the radius to the crown and that to the point E. Hence we get a value for the normal shear, $P \cos \theta - H \sin \theta$. As the point E is distant horizontally from the middle of the span an amount $r \sin \theta$, the last term of this expression for shear varies directly as the distance from the centre; and if we draw 3–7, in the stress diagram of Fig. 22, parallel to the radius at A, cutting 0–6 which is parallel to the tangent at A, 3–7 will be $H \sin \theta$ for A, and may be laid off at $a\,w$ and $b\,r$ of Fig. 23. The vertical ordinate $e\,d$ will then represent $H \sin \theta$ at any point. P_1 is laid off at $c\,l$, and P_2 at $c\,m$; with c as centre, and these two distances as radii, draw the dotted arcs seen in the figure; lay off several angles θ at c, as, for instance, $l\,c\,g$ and $m\,c\,n$ for the points E; project g and n horizontally to f under the respective points E;

df will be P cos θ, and from several similarly located points the curves $s\,l\,t$ and $v\,f\,r$ are found. Then at any point the *vertical* distance $df - e\,d$ or ef will be the *normal* shear in the web on the left of the section, positive if above the inclined line, negative if below it.

From the formula $P \cos \theta - H \sin \theta$, a table of shears may be easily computed for any given arch. $P \sin \theta + H \cos \theta$ will give the direct thrust.

89. **Distribution of Load to produce Equilibrium.** — A series of lines drawn in the stress diagram from 0, parallel to the tangents at a number of equidistant points in a circular rib, will cut off such portions of the load line as represent the loads necessary to make the successive sides of the equilibrium polygon parallel to these tangents, or, in short, coincident with the rib. But the lines radiating from 0 will successively intercept increasing lengths of load line. Hence the load which will keep a circular arch in equilibrium must increase in intensity per horizontal foot from the crown to the springing, and must become infinite at the springing of a semicircular arch. Hence it follows that no amount and distribution of vertical load can make a semicircular arch a true equilibrium curve, that is, one which has no bending moment at any point. In fact, no curve which starts vertically from the abutment can be an equilibrium curve under vertical loads. This may be seen in a more simple manner if we consider that no arrangement of weights will cause a cord, attached at two points, to hang in a funicular polygon whose first side is vertical.

90. **Effect of Change of Temperature.** — The horizontal thrust or tension, due to a change of temperature, in a circular rib hinged at the ends, is found by a similar method to that pursued for the parabolic rib. Referring, to avoid repetition, to what was said at that time, §§ 71–73, the equation may be written, as given in § 74,

$$H_t \,.\, \Sigma\, D\, E^2 = \pm\, 2\, \mathbf{E}\, \mathbf{I} \,.\, t\, e\, c.$$

Fig. 16 will answer for this case, if we imagine the arc to be

circular. As we saw, in § 82, that $\Sigma \mathrm{D\,E}^2$ for a semicircular arch was $\frac{1}{2}\pi r^3$, a substitution in the above equation gives at once

$$\mathrm{H}_t = \pm \frac{4\,\mathbf{E\,I}\,.\,t\,e\,c}{\pi\,r^3} = \pm\ 1.264\ \frac{\mathbf{E\,I}\,t\,e}{r^2}$$

for a semicircular rib. The bending moment at the crown, where it is a maximum, will be

$$\mathrm{M\ (max.)} = \frac{4\,\mathbf{E\,I}\,t\,e}{\pi\,r}.$$

If the arch is less than a semicircle, (*a.*), § 84, gives

$$\Sigma\,\mathrm{D\,E}^2 = r^3\,(\beta + 2\,\beta\cos^2\beta - 3\sin\beta\cos\beta),$$

and $c = r\sin\beta$; therefore, substituting, we obtain

$$\mathrm{H}_t = \pm\ \frac{2\,\mathbf{E\,I}\,t\,e\sin\beta}{r^2\,(\beta + 2\,\beta\cos^2\beta - 3\sin\beta\cos\beta)},$$

and the bending moment at the crown will be

$$\mathrm{M\ (max.)} = \frac{2\,\mathbf{E\,I}\,t\,e\sin\beta\,(1 - \cos\beta)}{r\,(\beta + 2\,\beta\cos^2\beta - 3\sin\beta\cos\beta)}.$$

91. **Shear from Change of Temperature.** — If a load of the proper amount and distribution were imposed on the rib to place it entirely in equilibrium, and cause it to exert against the abutments the desired value of H due to temperature, such a load would supply the amount of shear needed at each section, and, when the load is absent, the bracing must supply such shear. The line *w e c e r* of the shear diagram of Fig. 23 will therefore limit the ordinates for shear at right sections of the web under changes of temperature, when 0–3 is the amount of H_t. A reference to § 78 and § 87 will aid the reader in recalling these points.

CHAPTER VII.

CIRCULAR RIB WITH FIXED ENDS.

92. **Values of Equations of Condition.** — When the circular rib is fixed at the ends, we apply the three equations of condition which were developed in §§ 17–19, summing up the ordinates, however, along the arch, as has just been done in the preceding case, in place of the horizontal line. When the arch is a complete semicircle, or, as it is often called, a complete arch, as distinguished from a segmental one, the value of y_0, y_1, and y_2 may be obtained by a device similar to the one employed in § 82. The equation to satisfy the first condition is easily derived, but the two others present more difficulty; it is therefore not expedient to take up the semicircle as a special case, but rather to work out the general equations, and make the necessary substitutions.

In the arch of Fig. 24, let $AN = y_1$, $CK = y_0$, and $BR = y_2$; $MOB = MOA = \beta$, $MOI = \alpha$, and MOE, to any point E, $= \theta$, angles to the right of M being positive. The notation agrees with that just used. Then it may be proved that the three equations of condition will reduce to

$$\sin\beta\, y_0 + \tfrac{1}{2}(\sin\beta + \sin\alpha)\, y_1 + \tfrac{1}{2}(\sin\beta - \sin\alpha)\, y_2 = (\beta - \sin\beta\cos\beta)\, r; \quad (1.)$$

$$\begin{aligned} &- \sin\beta\,(\cos\alpha - \cos\beta + \alpha\sin\alpha - \beta\sin\beta)\, y_0 \\ &+ \tfrac{1}{2}(\sin\beta - \sin\alpha)(\cos\alpha - \cos\beta + \alpha\sin\alpha + \beta\sin\alpha)\, y_1 \\ &+ \tfrac{1}{2}(\sin\beta + \sin\alpha)(\cos\alpha - \cos\beta + \alpha\sin\alpha - \beta\sin\alpha)\, y_2 \\ &= (\sin\beta - \beta\cos\beta)(\sin^2\beta - \sin^2\alpha)\, r; \quad (2.) \end{aligned}$$

$$[(\beta - \cos\beta\sin\beta)\sin\alpha - (\alpha + \sin\alpha\cos\alpha - 2\sin\alpha\cos\beta)\sin\beta]\,y_0$$
$$+ \tfrac{1}{2}(\sin\beta - \sin\alpha)(\alpha + \sin\alpha\cos\alpha + \beta - \sin\beta\cos\beta - 2\sin\alpha\cos\beta)\,y_1$$
$$+ \tfrac{1}{2}(\sin\beta + \sin\alpha)(\alpha + \sin\alpha\cos\alpha - \beta + \sin\beta\cos\beta - 2\sin\alpha\cos\beta)\,y_2 = 0. \quad (3.)$$

It will be easier to solve the numerical equations after the values of α and β, with their sines and cosines, are introduced, than to deduce independent values of y_1, &c., at present. They may be written more briefly, for convenience in substitution, if

$$\sin\beta - \sin\alpha = a;\ \sin\beta + \sin\alpha = b;\ \alpha + \sin\alpha\cos\alpha - 2\sin\alpha\cos\beta = c;$$
$$\beta - \sin\beta\cos\beta = d;\ \cos\alpha - \cos\beta + \alpha\sin\alpha = e;$$

$$\sin\beta\, y_0 + \tfrac{1}{2}b\,y_1 + \tfrac{1}{2}a\,y_2 = d\,r. \quad (4.)$$

$$-(e - \beta\sin\beta)\sin\beta\,y_0 + \tfrac{1}{2}a(e + \beta\sin\alpha)\,y_1 + \tfrac{1}{2}b(e - \beta\sin\alpha)\,y_2$$
$$= a\,b(\sin\beta - \beta\cos\beta)\,r. \quad (5.)$$

$$(d\sin\alpha - c\sin\beta)\,y_0 + \tfrac{1}{2}a(c + d)\,y_1 + \tfrac{1}{2}b(c - d)\,y_2 = 0. \quad (6.)$$

93. **Special Values for Semicircular Rib.** — If the arch is a semicircle, $\beta = \frac{1}{2}\pi$; $\sin\beta = 1$; $\cos\beta = 0$; and the three equations of the last section reduce to

$$y_0 + \tfrac{1}{2}(1 + \sin\alpha)\,y_1 + \tfrac{1}{2}(1 - \sin\alpha)\,y_2 = \tfrac{1}{2}\pi r; \quad (1.)$$

$$(\tfrac{1}{2}\pi - \cos\alpha - \alpha\sin\alpha)\,y_0 + \tfrac{1}{2}(1 - \sin\alpha)(\cos\alpha + \alpha\sin\alpha + \tfrac{1}{2}\pi\sin\alpha)\,y_1$$
$$+ \tfrac{1}{2}(1 + \sin\alpha)(\cos\alpha + \alpha\sin\alpha - \tfrac{1}{2}\pi\sin\alpha)\,y_2 = (1 - \sin^2\alpha)\,r: \quad (2.)$$

$$(\tfrac{1}{2}\pi\sin\alpha - \alpha - \sin\alpha\cos\alpha)\,y_0 + \tfrac{1}{2}(1 - \sin\alpha)(\alpha + \sin\alpha\cos\alpha + \tfrac{1}{2}\pi)\,y_1$$
$$+ \tfrac{1}{2}(1 + \sin\alpha)(\alpha + \sin\alpha\cos\alpha - \tfrac{1}{2}\pi)\,y_2 = 0. \quad (3.)$$

If equation (1.) is multiplied by α, equation (3.) may be added to it, and then (2.) may be multiplied by $\sin\alpha$, and subtracted from their sum, when there will result

$$(\alpha + \tfrac{1}{4}\pi - \tfrac{1}{4}\pi\sin\alpha)\,y_1 + (\alpha - \tfrac{1}{4}\pi - \tfrac{1}{4}\pi\sin\alpha)\,y_2 = (\tfrac{1}{2}\pi\alpha - \sin\alpha)\,r. \quad (4.)$$

If (1.) is multiplied by $\frac{1}{2}\pi - \cos\alpha - \alpha\sin\alpha$, and equation (2.) is subtracted from it, we shall get, upon dividing by the common coefficient of y_1 and y_2,

$$\tfrac{1}{2}(y_1 + y_2) = \frac{\frac{1}{2}\pi(\frac{1}{2}\pi - \cos\alpha - \alpha\sin\alpha) - \cos^2\alpha}{\frac{1}{2}\pi - 2\cos\alpha - 2\alpha\sin\alpha + \frac{1}{2}\pi\sin^2\alpha}\,r,$$

which, if the quantity in the parentheses be represented by g, may be written,

$$\tfrac{1}{2}(y_1 + y_2) = \frac{\frac{1}{2}\pi g - \cos^2\alpha}{2g - \frac{1}{2}\pi\cos^2\alpha}\,r. \quad (5.)$$

Upon multiplying this equation by $2\alpha - \frac{1}{2}\pi \sin \alpha$, and subtracting it from (4.), we obtain, by factoring the second member,

$$\frac{1}{2}(y_1 - y_2) = \frac{\left(\frac{4}{\pi} - \frac{\pi}{2}\right)(a \cos^2 a - g \sin a)}{2g - \frac{1}{2}\pi \cos^2 a} r. \quad (6.)$$

The sum of (5.) and (6.) will give y_1; their difference will give y_2; and these values, inserted in (1.), will readily give us y_0.

94. **First Equation of Condition.** — Many of the following expressions are similar to those of § 84, and a remembrance of the relation between y_1 and y_2 will, in a measure, prevent the ensuing work from seeming so involved as it otherwise may appear. Generally, coefficients of y_1 and y_2 will differ only in the signs of the terms which contain a and sine a. The first condition is

$$\Sigma \, D E^2 = \Sigma \, D F \, . \, D E.$$

From § 84, we have

$$\Sigma \, D E^2 = r^3 (\beta + 2\beta \cos^2 \beta - 3 \sin \beta \cos \beta).$$

It will be seen, from Fig. 24, that $D F = D L + L F = y_1$ (or y_2) $+ L F$, D L in the sketch being negative on the right of K, and that, therefore, in place of the values of the section just referred to, we shall write

$$D F = y_1 + \frac{\sin \beta + \sin \theta}{\sin \beta + \sin a}(y_0 - y_1), \text{ on the left of K;}$$

$$D F = y_2 + \frac{\sin \beta - \sin \theta}{\sin \beta - \sin a}(y_0 - y_2), \text{ on the right of K.}$$

For the value of the second member of the above equation of condition between a and $-\beta$ we have then, since $D E = r(\cos \theta - \cos \beta)$,

$$r^2 \int_{-\beta}^{a} [y_1 (\cos \theta - \cos \beta) + \frac{y_0 - y_1}{\sin \beta + \sin a}(\sin \beta \cos \theta + \sin \theta \cos \theta - \sin \beta \cos \beta$$
$$- \cos \beta \sin \theta)]^* \, d\theta = r^2 [y_1 (\sin a - a \cos \beta + \sin \beta - \beta \cos \beta)$$
$$+ \frac{y_0 - y_1}{\sin \beta + \sin a}(\sin a \sin \beta - \tfrac{1}{2}\cos^2 a - a \sin \beta \cos \beta + \cos a \cos \beta$$
$$+ \sin^2 \beta - \tfrac{1}{2}\cos^2 \beta - \beta \sin \beta \cos \beta)].$$

Likewise, for the value of the second member between a and $+\beta$

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* Compare § 84.

$$r^2\int_\alpha^\beta [y_2(\cos\theta-\cos\beta)+\frac{y_0-y_2}{\sin\beta-\sin\alpha}(\sin\beta\cos\theta-\sin\theta\cos\theta-\sin\beta\cos\beta$$
$$+\cos\beta\sin\theta)]^{*}\,d\theta = r^2\,[y_2(\sin\beta-\beta\cos\beta-\sin\alpha+\alpha\cos\beta)$$
$$+\frac{y_0-y_2}{\sin\beta-\sin\alpha}(\sin^2\beta-\tfrac{1}{2}\cos^2\beta-\beta\sin\beta\cos\beta-\sin\alpha\sin\beta-\tfrac{1}{2}\cos^2\alpha$$
$$+\alpha\sin\beta\cos\beta+\cos\alpha\cos\beta)].$$

Equating the sum of these two quantities which make up the second member, with the first member, we obtain the first equation of condition, which, when cleared of fractions, becomes

$$y_0(2\sin^3\beta-\sin\beta\cos^2\beta-2\beta\sin^2\beta\cos\beta-\cos^2\alpha\sin\beta+2\cos\alpha\sin\beta\cos\beta$$
$$-2\sin^2\alpha\sin\beta+2\alpha\sin\alpha\sin\beta\cos\beta)+y_1(\tfrac{1}{2}\sin\beta\cos^2\beta-\sin^3\alpha$$
$$+\alpha\sin^2\alpha\cos\beta+\beta\sin^2\alpha\cos\beta+\tfrac{1}{2}\cos^2\alpha\sin\beta-\cos\alpha\sin\beta\cos\beta$$
$$-\tfrac{1}{2}\sin\alpha\cos^2\alpha-\alpha\sin\alpha\sin\beta\cos\beta+\sin\alpha\cos\alpha\cos\beta+\sin\alpha\sin^2\beta$$
$$-\tfrac{1}{2}\sin\alpha\cos^2\beta-\beta\sin\alpha\sin\beta\cos\beta)+y_2(\tfrac{1}{2}\sin\beta\cos^2\beta+\sin^3\alpha$$
$$-\alpha\sin^2\alpha\cos\beta+\beta\sin^2\alpha\cos\beta+\tfrac{1}{2}\cos^2\alpha\sin\beta-\cos\alpha\sin\beta\cos\beta$$
$$+\tfrac{1}{2}\sin\alpha\cos^2\alpha-\alpha\sin\alpha\sin\beta\cos\beta-\sin\alpha\cos\alpha\cos\beta-\sin\alpha\sin^2\beta$$
$$+\tfrac{1}{2}\sin\alpha\cos^2\beta+\beta\sin\alpha\sin\beta\cos\beta)=r(\sin^2\beta-\sin^2\alpha)(\beta+2\beta\cos^2\beta$$
$$-3\sin\beta\cos\beta).$$

95. **Second Equation of Condition.** — The next condition to be satisfied is $\Sigma\,D\,E=\Sigma\,D\,F$, or, introducing the values of these quantities from the preceding section,

$$r^2\int_{-\beta}^{+\beta}(\cos\theta-\cos\beta)\,d\theta=r\int_{-\beta}^{\alpha}[y_1+\frac{y_0-y_1}{\sin\beta+\sin\alpha}(\sin\beta+\sin\theta)]\,d\theta$$
$$+r\int_\alpha^\beta[y_2+\frac{y_0-y_2}{\sin\beta-\sin\alpha}(\sin\beta-\sin\theta)]\,d\theta.$$

Performing the indicated integration, and clearing of fractions, we obtain

$$y_0(2\beta\sin^2\beta-2\cos\alpha\sin\beta+2\sin\beta\cos\beta-2\alpha\sin\alpha\sin\beta)+y_1(-\beta\sin^2\alpha$$
$$-\alpha\sin^2\alpha+\cos\alpha\sin\beta-\sin\beta\cos\beta+\alpha\sin\alpha\sin\beta+\beta\sin\alpha\sin\beta$$
$$-\sin\alpha\cos\alpha+\sin\alpha\cos\beta)+y_2(-\beta\sin^2\alpha+\alpha\sin^2\alpha+\cos\alpha\sin\beta$$
$$-\sin\beta\cos\beta+\alpha\sin\alpha\sin\beta-\beta\sin\alpha\sin\beta+\sin\alpha\cos\alpha-\sin\alpha\cos\beta)$$
$$=2r(\sin^2\beta-\sin^2\alpha)(\sin\beta-\beta\cos\beta).$$

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* Compare § 84.

96. Third Equation of Condition.—The third condition, in the modified from of § 59, is Σ D E . D B = Σ D F . D B. Since D B = r (sin β — sin θ), this condition becomes, by multiplying the previous condition by D B,

$$r^3 \int_{\beta-}^{+\beta} (\sin\beta\cos\theta - \sin\theta\cos\theta - \sin\beta\cos\beta + \cos\beta\sin\theta)\, d\theta$$

$$= r^2 \int_{-\beta}^{\alpha} [y_1 (\sin\beta - \sin\theta) + \frac{y_0 - y_1}{\sin\beta + \sin\alpha} (\sin^2\beta - \sin^2\theta)\, d\theta$$

$$+ r^2 \int_{\alpha}^{\beta} [y_2 (\sin\beta - \sin\theta) + \frac{y_0 - y_2}{\sin\beta - \sin\alpha} (\sin^2\beta - 2\sin\beta\sin\theta + \sin^2\theta)]\, d\theta,^*$$

which, when integrated and cleared of fractions, gives

$$y_0 (2\beta\sin^3\beta - \alpha\sin\beta - \sin\alpha\cos\alpha\sin\beta + 2\sin^2\beta\cos\beta - 2\alpha\sin\alpha\sin^2\beta + \beta\sin\alpha + \sin\alpha\sin\beta\cos\beta - 2\cos\alpha\sin^2\beta) + y_1 (-\tfrac{3}{2}\sin^2\beta\cos\beta + \cos\alpha\sin^2\beta - \beta\sin^2\alpha\sin\beta - \alpha\sin^2\alpha\sin\beta + \sin^2\alpha\cos\beta - \tfrac{1}{2}\sin^2\alpha\cos\alpha + \tfrac{1}{2}\alpha\sin\beta - \tfrac{1}{2}\sin\alpha\cos\alpha\sin\beta + \tfrac{1}{2}\beta\sin\beta + \beta\sin\alpha\sin^2\beta + \alpha\sin\alpha\sin^2\beta - \tfrac{1}{2}\alpha\sin\alpha - \tfrac{1}{2}\beta\sin\alpha + \tfrac{1}{2}\sin\alpha\sin\beta\cos\beta) + y_2 (-\tfrac{1}{2}\sin^2\beta\cos\beta + \cos\alpha\sin^2\beta - \beta\sin^2\alpha\sin\beta + \alpha\sin^2\alpha\sin\beta - \sin^2\alpha\cos\beta + \tfrac{1}{2}\sin^2\alpha\cos\alpha + \tfrac{1}{2}\alpha\sin\beta + \tfrac{3}{2}\sin\alpha\cos\alpha\sin\beta - \tfrac{1}{2}\beta\sin\beta - \beta\sin\alpha\sin^2\beta + \alpha\sin\alpha\sin^2\beta + \tfrac{1}{2}\alpha\sin\alpha - \tfrac{1}{2}\beta\sin\alpha - \tfrac{3}{2}\sin\alpha\sin\beta\cos\beta) = 2r\sin\beta(\sin^2\beta - \sin^2\alpha)(\sin\beta - \beta\cos\beta).$$

97. Reduction of Equations.—If the second equation of condition is multiplied by cos β, and added to the first, there results an equation in which, as soon as we write 1 — sin² α for cos² α, and 1 — sin² β for cos² β, there will be found a common factor (sin² β — sin² α). This being cancelled out, there results (1.), § 92. The second equation again may be divided by 2, and then factored, by simple inspection, into (2.), § 92. Finally, the second equation of condition may be multiplied by sin β, and subtracted from the third, when, upon factoring, we obtain (3.), § 92.

It will be seen that the solution of (4.), (5.), and (6.), § 92, for any given arch, and for several values of α, will not involve much work, owing to the recurrence of the known factors denoted by a, b, c, d, and e. As the arch may subtend any angle, it will not be expedient to go into calculations here for any special values of β. One case will be taken up later.

98. Values of H, &c.—When the desired ordinates for any arch are computed, we have the option of obtaining the values

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* $\int \sin^2\theta\, d\theta = \tfrac{1}{2}(\theta - \sin\theta\cos\theta)$. See also note to § 84.

of H, of the vertical components of the abutment reactions, and of the ordinates for bending moment, either by graphical construction, or by formulæ similar to those applied to the parabolic rib. By noticing the expressions to be substituted for b, c, and k in the case of the circular arch with hinged ends, one can readily adapt the formulæ of § 63 and § 65 to the computations for this case. The ordinates to the circular arch will be the same as in § 85.

99. **Table of y_0, y_1, and y_2 for Semicircle.** — We may, however, obtain the ordinates y_0, &c., for a semicircle with comparative ease, and, as such a rib is sometimes used for large roofs, these values may be convenient. Semicircular masonry arches, having backing above the abutments, present a different case.

If α is taken as 20° or .3491, $\sin\alpha = .3420$, $\cos\alpha = .9397$, and $\frac{1}{2}\pi = 1.5708$; hence, in § 93, $g = .5117$, and (5.) and (6.) become

$$\tfrac{1}{2}(y_1 + y_2) = \frac{-.0792}{-.3646} r = .2172\,r;$$

$$\tfrac{1}{2}(y_1 - y_2) = \frac{-.2977 \times .1333}{-.3646} r = .1088\,r;$$

whence $y_1 = .326\,r$, and $y_2 = .108\,r$. By substitution in (1.), § 93, $y_0 = (1.5708 - .2187 - .0357)\,r = 1.316\,r$.

If similar computations are carried out for other values of α, we shall complete the following table for a semicircular rib with fixed ends:

α	y_1.	y_0.	y_2.
0°	.241 r	1.330 r	.241 r
10	.288	1.326	.183
20	.326	1.316	.108
30	.360	1.298	.011
40	.387	1.275	— .125
50	.413	1.245	— .330
60	.434	1.210	— .665
70	.455	1.170	— 1.333
80	.475	1.125	— 3.319

Other intermediate values can be obtained, if desired, by the

formula for interpolation, § 45. The number of decimals it is desirable to use in any particular case will depend upon the value of r. The equilibrium polygons for these ordinates have been drawn in Fig. 25, and from them we get the different values of H, for a weight W at the several divisions, as shown in the accompanying stress diagram.

100. **Example.**—As an application of these results, let us draw the equilibrium curve for a semicircular arch of uniform section carrying only its own weight. As this weight is symmetrically disposed, $y_1' = y_2'$. By drawing the stress diagram of Fig. 25 to a sufficiently large scale, we shall find by measurement, that H, for a weight at the crown, 10°, 20°, &c., from the crown, will be .46, .44, .39, .31, .23, .14, .07, .02, and .01 W respectively. If we double all of these values except the one for a weight at the crown, and take the sum of the whole, we shall obtain for the horizontal thrust, $H' = 3.68\,W$ for 17 loads, each equal to W, at the 17 points of division in the whole arch.

To find y_1', multiply each y_1 by its H, remembering, that, when the weights are on the left of the crown, the values of y_2 in the table of § 99 become y_1, and that we may, therefore, before multiplying by H, add together y_1 and y_2 for each point except the crown, and then divide the sum of these products by H′, just obtained. (Compare § 67.) For example, for a load W on each of the two points distant 30° from the crown, $H\,y_1 + H\,y_2 = .31\,W\,(.360 + .011)\,r = .115\,r\,W$, the value of M at the abutments. Performing the operations, and taking the algebraic sum of the products, we get $.6225\,r\,W$ for the total moment at either abutment, and $\dfrac{.6225\,r\,W}{3.68\,W} = 0.17\,r = y_1' = y_2'$.

To construct the equilibrium curve, we divide the semicircle A C B, Fig. 26, into eighteen equal parts, each subtending 10°, and draw verticals through the points of division. Assume the weight of the arch to be represented by a vertical line of any convenient length. Since the loads are supposed to be concentrated at the points of division, one-eighteenth of the gross

weight of the arch will be found at each of these points, and one-thirty-sixth at A and B; for A and B will each carry directly one-half of the adjacent division. Therefore, beginning and closing with one-thirty-sixth, space off the load-line into eighteenths; from the middle of the load-line lay off $H' = 3.68\,W = 3–0$, where $W =$ weight of one division, or $H' = \frac{3.68}{18} = .204$ of the whole weight of the rib. One-half of this load-line is 1–3. Lay off y_1' and $y_2' = .17\,r$, at A and B, and draw the sides of the equilibrium polygon parallel to the lines which radiate from the extremity of H' to the points of division of the load-line, thus obtaining the curve E G D. The second half of the curve was obtained by spacing off $0'–3$ to the left.

101. **Practical Application.** — Having at hand a wooden model of an arch-ring, representing the voussoirs, or stones, of a semicircular arch, we tried some experiments as tests of the accuracy of this method of analysis and of the correctness of these results. The arch is represented by Fig. 26, and consisted of forty-two independent voussoirs. The span, A B, of the middle line of the ring, 18 inches, was 13.09 times the thickness of the ring, and the structure would apparently just stand alone when left to itself: a slight additional weight at the crown would cause that part to sink, the haunches to move outwards, and the ring to fall in pieces. Considering that this arch, so long as it rested squarely on the faces at A and B, was fixed in direction, or not free to turn at the ends, we laid off at A E and B D the value of y_1 obtained in the last section, and drew the equilibrium polygon, as just described, on the centre line of the ring, beginning at D with a line parallel to 0–4. It will be noted that no line is used from 0 to 1; for the weight represented by 1–4 is directly supported at B; while the amount 4–5 is the weight concentrated on the first vertical just above D.

As the arch is a continuous ring, the weights may properly be concentrated at a greater number of points; so that finally the true equilibrium curve will pass through the vertices of the poly-

gon we have just constructed: the difference between the two is unimportant, however, and is only appreciable near the crown. The bending moment at any point has been proved to be equal to H multiplied by the vertical ordinate between the centre line and the equilibrium curve, or, by § 10, also equal to T, the thrust along the tangent to the equilibrium curve, multiplied by the perpendicular from a point on the centre line to this tangent: therefore if we draw E F as this tangent, the bending moment at A will equal either H. E A, or the thrust along E F multiplied by the perpendicular from A. The direction of the thrust E F, if prolonged, cuts the springing joint very close to the outside edge: it will also be noticed that the equilibrium curve approaches quite near to the edge of the voussoirs at the crown G. Now, as we reminded the reader in § 11 that the force T, or 0′–1, at the distance F A from the centre line of the rib, is equal to the same force at the centre line and the couple which produces bending moment, conversely, the resultant of the pressure of this rib at the end A must cut the base in the prolongation of the line E F: in short, the tangent to the equilibrium curve at each point gives the direction and point of application of the resultant thrust at that right section of the rib to which it belongs, as ascertained by erecting a vertical from the middle point of the section.

102. **Limiting Position of Equilibrium Curve.** — If, as is usually the case, the intensity of the resisting force of the abutment at A is assumed to vary uniformly from one edge to the other, then, in case the resistance is zero at the inside edge and a maximum at the outside edge, the intensity at all points can be represented, as shown in the small sketch marked A′, by the ordinates of a triangle whose base is the breadth of a voussoir, and whose longest ordinate is the intensity of the pressure at the edge near F. The total pressure will be equal to the area of the triangle, and the resultant will pass through the centre of gravity of the triangle, cutting the base at one-third of its length from the outer edge. If there existed any tension near the inner edge, we should have two triangles, as shown in the

other sketch, the inclined line cutting the base at the point where the stress changed from tension to compression; and the resultant of the two stresses must, since they are of opposite kinds, lie outside of their separate resultants, and on the side of the greater one. This fact as to the position of the resultant of two opposite parallel forces was indicated in § 11, Fig. 2, and is one of the well-known properties of the lever, as proved in Mechanics.

Since, then, the resultant force, or the thrust on a section of the rib of Fig. 26, at A, B, and C, passes near the edge of the section, or, as it is often stated, outside of the *middle third* of the cross-section, we should expect to find tension at the inside edge of the joint at these points. As this model consists simply of wooden blocks placed in juxtaposition, a voussoir cannot exert tension on its neighbor at any point of contact, and movement must immediately take place when the weight of the rib is allowed to act freely, rotation being set up about the outside edges at F, G, and Q. The crown will sink, the haunches will move outwards, and the arch may be expected to fall. The reader will remember that it was explained, in § 12, that an arch tends to move away from the equilibrium curve.

Since any material is compressible, it is probable that the assumption of a uniform variation of intensity of stress at any section will not be strictly true; that the stress may not be exerted over the entire surface of the *originally* plane joint; and that therefore the equilibrium curve may pass somewhat outside of the middle third of the joint without causing the arch to fall, although the joint will then open slightly at the edge where no pressure is exerted, by reason of the compression causing the joint to be no longer plane. But such an assumption gives an additional element of safety to a design, when the engineer so proportions his rib of rectangular section that the equilibrium curve of the load at any time shall never leave the limits of the middle third, and the tensile strength of the cement will not then be relied upon to assure stability.

103. **Model as hinged at Three Points.** — The arch of Fig. 26 stood when the string which at first passed around the exterior was removed, although a slight change of shape was observable. A close inspection, however, showed that the voussoirs at the crown and the two springings were then in contact only at the outer edges. The rotation at these joints, indicated in the last section as probable, had commenced; but, as soon as the rib became thus hinged at three points, it was in equilibrium. It is desirable, then, as a further test, to draw the equilibrium curve for this rib hinged at the crown and springings. As the change of shape and curvature was very little, the supposition that the weight of the voussoirs is concentrated along the arc K Q will be sufficiently near the truth for our purpose.

The half-weight being represented by 1–3, the first step is to find the value of H for this case, when the load is concentrated at intervals of ten degrees along the outer semicircle. We can avail ourselves of the formula of § 23, finding the different values of b by measurement, or from tables of sines, since $b = r \sin \theta$, and summing up the several amounts of H for the whole semicircle; or, as is done in this figure, we may use the principle explained in § 30, that any two sides of the funicular polygon, or two tangents to the equilibrium curve, will meet, when prolonged, on the vertical through the centre of gravity of the included weight. Since the arch is symmetrically loaded, the thrust at the crown will be horizontal, and therefore lie in the line K L; the centre of gravity of the quadrant arc K Q will be on the vertical line P L, drawn at such a distance, K L, from the crown as to satisfy the value for the ordinate from the centre of a circle to the centre of gravity of a circular arc, viz., $\dfrac{\text{radius} \times \text{chord}}{\text{length of arc}}$; and therefore the thrust at the springing will lie in the line Q L, drawn from Q to the intersection of the other two forces. As 1–3 represents the weight of one-half the arch, and the thrust at the crown is parallel to 3–0, a line from 1, parallel to Q L, will complete the triangle of forces, and,

cutting the horizontal line at 9, will determine 3–9 to be the desired value of H. The equilibrium polygon can now be drawn from Q to K, its sides being successively parallel to lines radiating from 9, the first line being 9–4 and the last one 9–6. These lines are not drawn in the stress diagram. The other half of the polygon may be added, if desired.

It will now be seen, that, excepting the hinged points, the nearest approach of the equilibrium curve to the edge of a voussoir is at P, where it is still well within the rib, and consequently no further movement of the rib is to be expected. Another model, somewhat thinner than the one here illustrated, was experimented with, and would not stand. If the arch of Fig. 26 is slightly weighted at K, the joint at P begins to open on the outside, confirming the result, that the equilibrium curve here passes nearest to the inner edge. If it be objected that the change of outline previously referred to carries the portion of the rib near P farther from the centre, so that the equilibrium curve may run nearer the edge than we have plotted it, we rejoin, that such a movement, carrying the centre of gravity, and hence the line P L, in the same direction, will cause Q L to make a slightly less angle with the vertical, diminishing the value of H, and moving the equilibrium curve also a little away from P.

104. **Model as hinged at Abutments.** — For the purpose of making an additional test of our results, we finally placed a small wire at A and B, thus hinging the rib on its centre line at these points. The equilibrium curve for one-half of the arch is A N K. The amount of H is determined by computation from the formula of § 85, which becomes, for a semicircular rib, $H = \frac{\cos^2 \alpha}{\pi} W$; and the summation for the whole arch, carrying W at intervals of ten degrees along the centre line, is $H = 2.86\ W$, laid off at 3–8. Radiating lines between 8–4 and 8–6 will enable one to draw A N K. The arch, when released, fell in ruins, and the first joint to open, on the outside at the haunch, was near N, lower than P in the former case.

We have dwelt on these curves at some length, as they give so good a confirmation of previous deductions and results, and as they will aid the reader in assuring himself that he understands the method of treatment. Such diagrams must, for accuracy, be drawn to quite a large scale, and the results will then be very satisfactory.

105. **Effect of Change of Temperature.** — It remains to find the effect of change of temperature on the circular rib with fixed ends. As was previously indicated in § 76, we must find the height $A\,G = B\,I = y_1$, at which the equilibrium line shall be drawn in Fig. 27, by the condition that the change of inclination at the abutments, or $\Sigma\, E\,F = 0$. If the notation of the angles subtended by portions of the arch is as before, and as marked in the figure, we have $E\,F = D\,E - y_1$, and

$$\Sigma\, E\,F = \int_{-\beta}^{+\beta} r\,(r\cos\theta - r\cos\beta - y_1)\,d\,\theta = 2r\,(r\sin\beta - r\,\beta\cos\beta - y_1\,\beta) = 0,$$

or

$$y_1 = r\left(\frac{\sin\beta}{\beta} - \cos\beta\right),$$

which becomes, for a semicircle,

$$y_1 = \frac{2\,r}{\pi} = 0.632\,r.$$

The first term of (1.), § 76, therefore becomes $\Sigma\,D\,E^2 - y_1\,.\,\Sigma\,D\,E$. From § 84, $\Sigma\,D\,E^2 = r^3\,(\beta + 2\,\beta\cos^2\beta - 3\sin\beta\cos\beta)$, while $y_1\,.\,\Sigma\,D\,E$ gives, as above, $r^3\left(\frac{\sin\beta}{\beta} - \cos\beta\right)(2\sin\beta - 2\,\beta\cos\beta)$; so that the first term reduces to $r^3\left(\beta + \sin\beta\cos\beta - \frac{2\sin^2\beta}{\beta}\right)$, and (1.), § 76, takes the form of

$$H_t\,.\,r^3\left(\beta + \sin\beta\cos\beta - \frac{2\sin^2\beta}{\beta}\right) = \pm\,2\,\mathbf{E\,I}\,t\,e\,r\sin\beta.$$

$$H_t = \pm\,\frac{2\,\mathbf{E\,I}\,t\,e}{r^2\left(\frac{\beta}{\sin\beta} + \cos\beta - 2\,\frac{\sin\beta}{\beta}\right)}.$$

For a semicircle, the formula for horizontal thrust simplifies into

$$H_t = \pm \frac{2 E I t e}{r^2\left(\frac{\pi}{2} - 2\frac{2}{\pi}\right)} = \pm\, 6.45 \frac{E I t e}{r^2}.$$

The bending moments at the crown and springing can now be readily written, and compared with the values of § 90. The horizontal thrust for the semicircular rib fixed at the ends is five times as great as when the ends are hinged. The remarks of § 91 in regard to shear will apply equally well here.

For the Elliptic Rib, see § 153.

106. **Maximum Stress determined by Length of Ordinate; Rib of Rectangular Section.** — It may sometimes be convenient to have the means of determining from a simple inspection of a diagram, by noting the position of the equilibrium polygon, how much the maximum intensity of stress at any section exceeds the mean intensity. As the mean intensity $f = T \div S$ where T is the direct thrust and S is the area of cross-section, and is obtained at any point from the known value of the thrust in the side of the equilibrium polygon, the maximum intensity of stress will be readily found by multiplying by the proper ratio. The stress arising from bending moment in a solid section is always taken as uniformly varying (see Fig. 2). The combination of direct stress with that from bending moment will also give a uniformly varying stress.

Considering, first, the rib of rectangular cross-section, Fig. 28, we see, that if we call the intensity, A C, of direct stress unity, a bending moment which will produce a compression, D E, of unity at the upper extreme fibre, and a tension, C A, of unity at the lower extreme fibre, will bring the resultant stress at all points to the amounts indicated in the left-hand sketch, twice the mean intensity at one edge, and zero at the other. If the cross-section is treated by the method of Part I., "Roofs," p. 57, Fig. 24, in order to make an equivalent area of uniform stress equal to the maximum, we get the shaded area of the section on the left, which is evidently one-half of the whole

section. The centre of gravity of this area, lying at one-third the height from the upper edge, will be the point of application of the resultant force on the cross-section. If the bending moment is reversed, the sketch will be inverted: hence, when the line of thrust, or the side of the equilibrium polygon, passes at *one-sixth* of the depth above or below the *axis* of the rib, the intensity of stress at that edge of the rib which is nearer the line of thrust will be twice the mean intensity.

If, again, the maximum intensity is to be thrice the mean, the line F G, starting at a distance B F = 3 B D, still cuts C D at its middle point in order to make the total tension from bending moment equal to the total compression from the same cause. Noting where F G cuts A B, we have the point of no stress at $\frac{3}{4}\,h$ from the upper edge of the section: hence the shaded areas are drawn as given in the section on the right, the upper one for compression, the lower one for tension. The area of the upper one is $\frac{1}{2}\,b\,.\,\frac{3}{4}\,h = \frac{3}{8}\,b\,h$: the lower one, being similar, but of one-third the altitude, has one-ninth the area of the other, or $\frac{1}{24}\,b\,h$. The difference is $\frac{1}{3}\,b\,h$, or one-third the area of the cross-section, as required if the maximum intensity is to be three times the mean. Letting these areas represent the forces, and taking moments about the upper edge, each force being applied at the centre of gravity of its triangle, we have for the position of the resultant, measured from the upper edge,

$$\frac{\frac{3}{8}\,b\,h\,.\,\frac{1}{4}\,h - \frac{1}{24}\,b\,h\,.\,\frac{11}{12}\,h}{\frac{1}{3}\,b\,h} = \frac{1}{6}\,h.$$

If, therefore, the line of thrust passes at $\frac{1}{6}\,h$ from the edge, or one-third the depth from the axis, the intensity of compression on the outside fibre nearer the line will be three times the mean compression, and at the other edge there will be a tension equal in magnitude to the mean stress.

In the same way it may be shown, that, when the line of thrust cuts the edge, the compression there will be B I, four times the mean, and the tension at the other edge will be A K, twice the magnitude of the mean stress. Thus it will be seen,

that, for every one-sixth h that the line of thrust is distant from the axis, the compression on the square inch will be increased by unity on the side to which the line deviates, and diminished by unity on the other side, the mean compression being denoted by unity. This is indicated by the numerals marked on the sketches of Fig. 29.

107. **Rib of Two Flanges.** — If the rib is composed of two flanges and an open-work web, the stress in either flange is easily determined. If the line of thrust is in the axis, each flange will carry one-half of the direct stress. If the line of thrust passes through one flange, Fig. 30, that flange may be considered to carry all of the compression uniformly distributed, and the other flange to be under no stress; for the depth of the flange is so small, compared with the whole depth of the rib, that no error of importance is involved in considering the stress as uniformly distributed over the section of one flange. If the line of thrust passes without the rib a distance equal to its depth, we get, by taking moments at A, Fig. 30,

$$\text{Thrust at C} \times 2\,\text{A B} = \text{Compression at B} \times \text{A B};$$
$$\text{or, } \textit{Compression} \text{ at B} = 2 \times \text{direct stress.}$$

If moments are taken at B, we find,

$$\textit{Tension} \text{ at A} = \text{direct stress.}$$

In the same way, if $B'C' = 2\,A'B'$,

$$\text{Compression at } B' = 3 \times \text{direct stress; Tension at } A' = 2 \times \text{direct stress.}$$

Hence we may draw a sketch for this rib similar to the one for the rectangular rib. The numerals here denote that one flange carries once, twice, &c., the *entire* direct stress. If the rib has a plate web, or is an I beam, the above method will give a good approximation to the true stresses. If the web is heavy, the method of the next section may be applied.

108. **Rib of Circular Section; General Construction.** — When the rib is of less simple section, we must return to the

graphical construction first referred to. As an instance, suppose the cross-section of the rib to be a circle. The variation of stress on a diameter, in the direction of deviation, is indicated by the left-hand sketch of Fig. 31, when the intensity of stress is twice the mean at one edge, and zero at the other. By constructing, according to the principles already laid down, Part I., "Roofs," the equivalent area of maximum intensity, we obtain the shaded area of the figure, and then we determine its centre of gravity by cutting out the area, and balancing it over a knife-edge. The deviation of the line of thrust from the centre of the circle, to make the maximum intensity twice the mean, and the minimum zero, is thus found, and proves to be one-fourth the radius.

By the construction of the other sketch, taking moments as in § 106, or reasoning by analogy, we find that the deviation, in order that the maximum shall be thrice the mean intensity of compression, and the tension at the other end of the diameter shall equal the mean stress, must be one-half the radius from the centre: hence, when the line of thrust cuts the edge, the maximum compression equals five times the mean, and the tension at the other extreme of the diameter is three times the mean compression. Thus we get the numerals and their positions, as given in the figure.

In a thin tube of circular, elliptical, or oval section, the maximum compression is nearly three times the mean intensity of direct stress where the equilibrium polygon cuts the surface of the tube; and a tensile stress equal in magnitude to the mean will then be found at the other end of the extremity of the diameter: hence proportionate distances of the side of the equilibrium polygon from the axis of the rib will give twice, four times, &c., the mean stress.

CHAPTER VIII.

ARCHED RIBS UNDER WIND PRESSURE: HORIZONTAL FORCES.

109. **Wind Pressure on an Inclined Surface.** — When arched ribs are used, as is often the case, for the support of a roof, the pressure of the wind, being normal to the surface, will have a different effect upon the arch from that caused by a simple weight or vertical force. While referring to Part I., "Roofs," p. 31, for some remarks about the action of wind on a roof, we will repeat here, that, if P equals the horizontal force of the wind on a square foot of a vertical plane, the perpendicular pressure on a square foot of a surface inclined at an angle i to the horizon may be expressed by the empirical formula, —

$$P \sin i^{1.84 \cos i - 1}.$$

If, then, the maximum force of the wind be taken as forty pounds per square foot, which is an amount sufficiently great for the purposes of a design, the perpendicular or normal pressure per square foot, on surfaces inclined at different angles to the horizon, will be: —

Angle of Roof.	Normal Pressure.	Angle of Roof.	Normal Pressure.
5°	5.2 lbs.	35°	30.1 lbs.
10	9.6	40	33.4
15	14.0	45	36.1
20	18.3	50	38.1
25	22.5	55	39.6
30	26.5	60	40.0

For steeper pitches, the pressure may be taken as forty pounds.

The resultant pressure at each of the joints in the rafter which is on the side of the wind is then ascertained as in the case of any roof. If the roof surface is curved, any short portion between two points where braces abut, or purlins rest, may be considered as straight, and the wind force will then be perpendicular to such portion; this pressure being the only force exerted by the wind. If the resultant pressure at each joint is then found, either graphically or otherwise, and is resolved into vertical and horizontal components, we may include the vertical component in the analysis already carried out in detail. The effect of the horizontal component remains to be considered.

110. **Form of the Equilibrium Polygon; Vertical Component of Reaction.** — The tendency of such a force to distort the arch being resisted by the stiffness of the rib, the equilibrium polygon for a single horizontal force H, applied at any point I on the rib, Fig. 32, must, if the arch is hinged at the ends, be two straight lines, which start from the two springing points, and meet on the prolongation of the line of action of H; for the rib must be in equilibrium under H and the two forces at the abutments. In the case of the arch A C B of Fig. 32, the reactions at A and B must lie in the lines A G and B G, the point G being found on the horizontal line I G, but its location on that line being at present unknown. It will be evident, when we conceive H to be applied to the equilibrium polygon at G, that the side A G will be in *tension*, while G B is compressed: therefore the reaction at B will be a thrust, as usual, but that at A will be a tension; and, if H were the only applied force, the arch would tend to rise from the abutment A, and would require fastening down.

As H acts at a vertical distance I L above the springing line, the moment which tends to overturn the frame is H . I L. If we take either abutment as the axis of moments, the condition of equilibrium that the moments of exterior forces must balance

gives $H \,.\, IL = P \,.\, AB$; and consequently the vertical component of the reaction at either abutment is, —

$$P = H \frac{IL}{AB},$$

being tension at the side nearer to I, and compression on the other side. H will be partially resisted at each abutment. The stress diagram will be a figure like 1 2 3, in which 3–4 and 4–1 are $-P$ and H_1 for A, while 2–4 and 4–3 are H_2 and $+P$ for B, 1–2 being equal to H.

111. **Rib hinged at Three Points.** — As was the case with arches under vertical forces only, so also with ribs under a wind pressure: the hinging of the rib at three points makes the analysis at once very simple. If the arch of Fig. 32 is pivoted or jointed at A, C, and B, C being usually taken at the crown of the rib, and the external horizontal force H is applied at I, the line of thrust for the right-hand portion of the arch must be B C. This will be plainly seen, if we consider that the part B E C of the rib is supported by a reaction at B and the thrust of the other half of the arch at C, while there is no other force exerted upon it: for equilibrium, therefore, these two forces must lie in one straight line, which can be no other than B C, drawn through the two points of application. Then, as proved before, the reaction at A must lie in A G, drawn to the intersection of H with B C. It may be noted that 1–4, or H_1, is always greater that one-half of H.

112. **Value of Bending Moments.** — If we make a section at any point E on the right of C, the only force acting on the right of the section is the inclined reaction at the abutment B. The bending moment at E is, therefore, equal to (3–2) E N, or to either of the equal products $H_2 \,.\, EF$ and $P \,.\, EK$. The bending moment at any point between C and I, for the same reason, will still be expressed by $H_2 \,.\, EF$ or $P \,.\, EK$, but will be of the opposite kind, since we passed a point of no bending moment at C, and E F or E K is drawn in a reverse direction. For sections between I and A it will be easier to take the force on the left

of the plane of section, which will be the tension of the left abutment, as this is the only force on that side: the bending moment will therefore be $H_1 . E F$ or $P . E K$. It will be perceived, on a little reflection, that these moments will agree in kind with those between C and I; the reversal of the ordinate E F from the outside to the inside of the rib offsetting the change from H_2, compression, to H_1, tension. The application of H at I to a moderately flexible wire of the shape A C B would flatten the left portion, and make the right portion more convex.

We may very simply consider the bending moment at any point of the rib to be represented by the product $P . E K$, where E K is the horizontal distance or abscissa from E to the equilibrium polygon. We thus have an evident analogy between the equilibrium polygons for horizontal and for vertical forces, if the ordinate for bending moment is taken parallel to the applied force, and is then multiplied by a constant, P in this case, H in the other. The point of contraflexure is where the polygon meets the rib, and one point of maximum flexure is at I, the point of application of the external force.

The insertion of pivots at three points of the rib enables one to draw the equilibrium polygon at once for one or all of the forces to which the roof may be at one time subjected, and we will therefore proceed, without further delay, to consider the case of the parabolic rib hinged at the abutments only.

113. **Parabolic Rib hinged at Abutments; Formula for** x_0 — If Fig. 33 represents a parabolic rib hinged at A and B, with a horizontal force H applied at I, the point of intersection of A G and B N must be determined. Since it will lie upon the horizontal line drawn through I, the distance of G horizontally from the middle of the span will be denoted by x_0, positive when measured from the middle away from I. The well-known condition that change of span shall be zero may be put either

$$\Sigma H_2 . E F . D E \text{ (from B to I)} + \Sigma H_1 . E F . D E \text{ (from A to I)} = 0,$$

or

$$P . \Sigma E K . D E = 0, \quad (1.)$$

in which latter expression P, being constant, may be omitted. If b, as usual, denotes the horizontal distance of I, the point of application of the force, from the middle of the span, and c equals the half-span, we can find that

$$x_0 = \frac{b^3}{4\,c^4}\,(5\,c^2 - b^2) = \tfrac{1}{4}\,n^3\,(5 - n^2)\,c, \qquad (2.)$$

when $b = n\,c$. We shall see that x_0, depending for its sign upon that of b, will always be laid off on the opposite side of the centre from b, since it is so first taken in the figure, and hence that H_1, the horizontal *tension*, is always greater than one-half of H. The value of x_0 is independent of k.

114. **Proof of Formula.** — Retaining the usual notation, we have $A\,L = c - b$, $L\,B = c + b$; and $G\,Q = I\,L = \frac{k}{c^2}\,(c^2 - b^2)$. If x denotes the horizontal distance, B D, to the abutment, from any ordinate, D E, on the right of I we have

$$D\,E = \frac{k}{c^2}\,(2\,c\,x - x^2), \text{ and } D\,F : D\,B = G\,Q : Q\,B, \text{ or } D\,F = \frac{k}{c^2}\,(c^2 - b^2)\,\frac{x}{c - x_0}.$$

As $E\,K : E\,F = Q\,B : G\,Q$, and $E\,F = D\,E - D\,F$, we have

$$E\,K = (D\,E - D\,F)\,\frac{Q\,B}{G\,Q}, \text{ and } E\,K\,.\,D\,E = (D\,E^2 - D\,E\,.\,D\,F)\,\frac{Q\,B}{G\,Q}.$$

Substituting the values of these quantities, we get

$$\Sigma\,E\,K\,.\,D\,E = \int \frac{k}{c^2}\left[(2\,c\,x - x^2)^2 - (2\,c\,x - x^2)\,x\,\frac{c^2 - b^2}{c - x_0}\right]\frac{c - x_0}{c^2 - b^2}\,d\,x$$

as the expression which is applicable from B to I. From A to I the abscissa E K will be limited by the line A G, which differs in inclination from B C. If x, however, is now reckoned from A to the right, and A Q, denoted by $c + x_0$, is used in place of Q B, we have an expression for the space from A to I. This expedient was used in previous sections. As A G is in tension while B C is compressed, these two portions of (1.), § 113, will have opposite signs, and, when integrated, must be equal: we may, therefore, in equating, strike out the common constant quantities, obtaining

$$(c - x_0)\int_0^{c+b}(4\,c^2\,x^2 - 4\,c\,x^3 + x^4)\,d\,x - (c^2 - b^2)\int_0^{c+b}(2\,c\,x^3 - x^3)\,d\,x$$

$$= (c + x_0)\int_0^{c-b}(4\,c^2\,x^2 - 4\,c\,x^3 + x^4)\,d\,x - (c^2 - b^2)\int_0^{c-b}(2\,c\,x^3 - x^3)\,d\,x.$$

Performing the indicated integration, we get

$$(c-x_0)\left[\tfrac{4}{3}c^2(c+b)^3-c(c+b)^4+\tfrac{1}{5}(c+b)^5\right]-(c^2-b^2)\left[\tfrac{2}{3}c(c+b)^3-\tfrac{1}{4}(c+b)^4\right]$$
$$=(c+x_0)\left[\tfrac{4}{3}c^2(c-b)^3-c(c-b)^4+\tfrac{1}{5}(c-b)^5\right]-(c^2-b^2)\left[\tfrac{2}{3}c(c-b)^3-\tfrac{1}{4}(c-b)^4\right],$$

which at once reduces to

$$\tfrac{16}{15}c^5 x_0 = \tfrac{4}{3}c^3 b^3 - \tfrac{4}{15}c\,b^5,$$

or

$$x_0 = \frac{b^3}{4\,c^4}(5\,c^2 - b^2).$$

115. **Another Proof.**—We may, if we please, find the desired distance x_0 by another method. Imagine the roof of Fig. 34 to have two equal but opposite forces, H, applied at the two points C and G in the same horizontal line. These forces, if acting alone, will tend to diminish the span of the roof; there will be no vertical forces; and as the bending moments caused by them, in case the rib did not rest upon abutments, would be directly proportional to E F, the change of span would be proportional to Σ E F . D E from C to G. When the rib is retained by abutments, one H will give rise to H_1 at A, and H_2 at B: the other H will cause H_2 at A, and H_1 at B. As H_1 is always opposite in sign to H_2, the resultant force at each abutment will be $H_1 - H_2$, and is manifestly a tension exerted by the abutment on the rib. The change of span due to $H_1 - H_2$ will be proportional to $\Sigma\,\mathrm{D\,E}^2$ from A to B (compare § 74), and this change of span must offset the one from H.

If D is at a distance x from the middle of the span, and C is distant b from the same point, we have $\mathrm{D\,E} = \frac{k}{c^2}(c^2 - x^2)$, and $\mathrm{E\,F} = \frac{k}{c^2}(b^2 - x^2)$. Since the rib is acted upon symmetrically, we need only integrate from the middle to one side; and we therefore have, when we drop the common factor $\frac{k}{c^2}$,

$$(\mathrm{H}_1 - \mathrm{H}_2)\int_0^c (c^2 - x^2)^2\,dx = \mathrm{H}\int_0^b (b^2 - x^2)(c^2 - x^2)\,dx,$$

or

$$(H_1 - H_2) \tfrac{8}{15} c^5 = H (\tfrac{2}{3} b^3 c^2 - \tfrac{2}{15} c^5). \quad (a.)$$

From the stress diagram of Fig. 33 we see that

$$H_1 : H_2 : H = c + x_0 : c - x_0 : 2c;$$

whence

$$H_1 - H_2 = H \frac{c + x_0 - c + x_0}{2c} = H \frac{x_0}{c}.$$

Substituting this value in $(a.)$ we get, as before, § **114**,

$$x_0 = \frac{b^3}{4c^4} (5c^2 - b^2).$$

116. **Formulæ for H_1 and P.** — The value of H_1 is seen to be, from the above proportion,

$$H_1 = H \frac{c + x_0}{2c} = H \left(\tfrac{1}{2} + \frac{x_0}{2c}\right) = H \left[\tfrac{1}{2} + \frac{b^3}{8c^5} (5c^2 - b^2)\right].$$

We also have, from Fig. 33,

$$P : H = GQ : AB = \frac{k}{c^2} (c^2 - b^2) : 2c;$$

or

$$P = H \frac{k}{2c^3} (c^2 - b^2) = H \frac{k}{2c} (1 - n^2).$$

The reader may now calculate, if desirable, numerical values of x_0, H_1, and P, for different values of b, as was previously done for vertical forces. The several values of x_0 for four different positions of H are plotted in Fig. 33.

117. **Shear and Direct Stress.** — The shear will undergo some modification when the force applied to the arch acts horizontally, instead of vertically. The stress diagram is, as we have seen, a triangle, whose base is H, and whose altitude is P, represented by 0 1 2 of Fig. 36. At A of the parabolic rib the *thrust* is 1–0: if 1–4 is drawn parallel to the tangent at A, and 0–8 perpendicular to it, 1–8 will be the direct thrust, and 8–0 the negative shear, on a right section at A. This shear will

diminish at successive sections until we reach a point where the tangent to the rib is parallel to A G, when the shear will be zero, and the direct thrust 1–0. Beyond this point the shear will be positive until we pass I. At the abutment B, there is a *tension* 2–0: if 2–7 is drawn parallel to the tangent at B, 2–9 will be the direct tension, and 9–0 the shear, again negative, on a right section at B. In the same way the shear just to the left of I will be 10–0, positive, and to the right of I, 11–0, negative. It will be remembered that positive shear acts upward on the left of any section.

118. **Shear Diagram.** — A shear diagram may be drawn for a rib under a horizontal force by a similar method to the one previously explained, showing the *vertical* shear which will be projected on each right section. Lay off at a the quantity $P = 3\text{–}0 = af$, which is the vertical component of the reaction at A, and as P is constant across the entire span, being, in fact, the only external vertical force, complete the rectangle $afdb$. The vertical component which is required at A to produce 1–4 is 3–4, laid off at ae; and at B is 3–7, laid off above the line at bl, because 0–2 is a tension. A load of uniform intensity horizontally being required to put a parabolic rib in equilibrium, and H_1 being constant as far as I, draw ecg through c, the middle point of ab, and draw ln so as to pass through c, if prolonged. Then will the vertical ordinates between the inclined lines and fd represent the shear on a *vertical* section, and the projection of these ordinates on the respective normal sections will be the shear in the web. Thus ef is 4–0, which gives by projection 8–0, ig is 0–5, and in is 0–6. As in previous diagrams, the ordinates will be measured from the inclined lines, positive above and negative below, as marked. The shear will change sign at the point of maximum bending moment, and it will plainly be equal to P at the crown of the arch.

If it is remembered that the abutment reaction at B is of the opposite kind to that at A, or to the usual reaction for a weight W, the rotation of the diagram on the right of i, from the customary position below the line to its present place above

$a\,b$, will be accounted for. The force H has been assumed on the right in Fig. 36, in order that this shear diagram may be compared with that of Fig. 8. The vertical shear from a normal force may be found from an addition of these two figures. Moment diagrams cannot be added together in the same way, as the values of H and H_1 or H_2 will not be the same in the two cases.

119. **Circular Rib hinged at Ends.** — The method of finding x_0, introduced in § 115, is easily applied to the circular rib hinged at the ends; while the process of § 114 is considerably more involved. Let the angle subtended, in Fig. 35, by the half arch of radius r be denoted by β; the angle from the crown to the point of application of the external horizontal force, H, be α; and the variable angle from the crown to any point be θ. Let H be applied at two opposite points at the same level, as shown by the arrows in the figure, and let the abutment reactions be $H_1 - H_2$. Then, by parallel reasoning to that of § 115, we have, if y denotes any ordinate, and a the ordinate to the point of application of H,

$$(H_1 - H_2)\int_0^\beta y^2\,d\,s = H\int_0^\alpha (y - a)\,y\,d\,s.$$

$$y = r\,(\cos\theta - \cos\beta);\quad a = r\,(\cos\alpha - \cos\beta);\ \therefore$$

$$(H_1 - H_2)\,r^3\int_0^\beta (\cos^2\theta - 2\cos\theta\cos\beta + \cos^2\beta)\,d\,\theta$$

$$= H\,r^3\int_0^\alpha (\cos^2\theta - \cos\theta\cos\beta - \cos\theta\cos\alpha + \cos\alpha\cos\beta)\,d\,\theta.$$

Performing the integration, we get

$$(H_1 - H_2)\,(\tfrac{1}{2}\beta - \tfrac{3}{2}\sin\beta\cos\beta + \beta\cos^2\beta)$$
$$= H\,(\tfrac{1}{2}\alpha - \tfrac{1}{2}\sin\alpha\cos\alpha - \sin\alpha\cos\beta + \alpha\cos\alpha\cos\beta).$$

As in § 115, $x_0 = \dfrac{H_1 - H_2}{H}\,c = \dfrac{H_1 - H_2}{H}\,r\sin\beta$: whence

$$x_0 = r\sin\beta\,\frac{\alpha - \sin\alpha\cos\alpha - 2\cos\beta\,(\sin\alpha - \alpha\cos\alpha)}{\beta - 3\sin\beta\cos\beta + 2\,\beta\cos^2\beta}. \quad (1.)$$

If the rib is a semicircle, $\beta = \frac{1}{2}\pi$; $\cos\beta = 0$; $\sin\beta = 1$; and (1.) becomes,

$$x_0 = \frac{2r}{\pi}(a - \sin a \cos a). \quad (2.)$$

120. **Formulæ for H_1 and P.** — The value of H_1 will be, as in § 116,

$$H_1 = H\frac{c + x_0}{2c} = H\left(\tfrac{1}{2} + \frac{x_0}{2r\sin\beta}\right)$$

$$= \tfrac{1}{2}H\left(1 + \frac{a - \sin a \cos a - 2\cos\beta(\sin a - a\cos a)}{\beta - 3\sin\beta\cos\beta + 2\beta\cos^2\beta}\right),$$

and

$$P = \frac{Ha}{2c} = \frac{\cos a - \cos\beta}{2\sin\beta}H;$$

or, for a complete semicircle,

$$H_1 = \frac{\frac{1}{2}\pi + a - \sin a \cos a}{\pi}H; \quad P = \tfrac{1}{2}\cos a\, H.$$

121. **Experimental Verification.** — The values of x_0, obtained above, can be readily shown to be true by turning the model previously referred to through an angle of ninety degrees. A moderately stiff wire carefully bent to a curve A G B, Fig. 37, symmetrical with regard to the point G (an arc of a circle being probably the easiest one to fashion), is suspended from points C and D by strings from A to C, and from B to D. If the string B D is doubled so as to pass on both sides of the wire above G, A G B will be prevented from swinging round. A thread from A to B will hinder the span from enlarging, and will indicate by its slackening when the span is narrowed. If, then, a weight is attached at E, and, the string at C remaining stationary, that at D is moved until B is vertically below A, as proved by plumbing the thread A B, C A, when prolonged, will be found to intersect B D at F in the vertical line E F, giving the desired value of x_0. The point of intersection will be slightly changed by the weight of the wire, as before suggested in § 81. It is worthy of note that, H now being an external pull on the rib, in place of the usual thrust, x_0 will, in Fig. 37, be found on the same side of the centre with H.

122. Parabolic Rib fixed at Ends; Formulæ for x_0, x_1, and x_2. — Referring to Fig. 38, we will suppose that the external force H is applied at I, on the left of this parabolic rib with fixed ends; that the desired equilibrium polygon is given by the lines L G and N G C; and that the abscissæ, at present unknown, are, A L $= x_1$, B N $= x_2$, and O Q $= x_0$, the latter being measured from the middle of the span, and all being considered as positive when laid off as shown in this figure. The rest of the notation agrees with that used before. It may be proved that the abscissæ have the following easily computed values:

$$x_1 = \tfrac{1}{3}\left(c + \frac{4\,b^2}{c - b}\right); \quad x_2 = \tfrac{1}{3}\left(c + \frac{4\,b^2}{c + b}\right); \quad x_0 = 2\,\frac{b^3}{c^2},$$

or

$$x_1 = \tfrac{1}{3}\,c\left(1 + \frac{4\,n^2}{1 - n}\right); \quad x_2 = \tfrac{1}{3}\,c\left(1 + \frac{4\,n^2}{1 + n}\right); \quad x_0 = 2\,n^3\,c.$$

Several of these values, for different positions of H, are plotted in Fig. 38.

If b is given successive values from $0.1\,c$ to $0.9\,c$, these quantities will be found to be

b.	x_1.	x_0.	x_2.
$0.1\,c$	$0.35\,c$	$0.002\,c$	$0.35\,c$
.2	0.40	0.016	0.38
.3	0.50	0.054	0.43
.4	0.69	0.128	0.49
.5	1.00	0.250	0.56
.6	1.53	0.432	0.63
.7	2.51	0.688	0.72
.8	4.60	1.024	0.81
.9	11.17	1.442	0.90

If b exceeds $0.7\,c$, the point of intersection falls without the rib.

123. First Equation of Condition. — If we remark that Q G, Fig. 38, the ordinate to the line of action of H, will be equal to I S, or to $\frac{k}{c^2}(c^2 - b^2)$, and that R K $=$ D E, we may find the value of E K as follows:

$$EK = RN - DN;\ RN : RK = QN : QG, \text{ or } RN = \frac{RK \cdot QN}{QG};$$

therefore

$$EK = \frac{DE \cdot QN}{QG} - DN.$$

These quantities, in the notation employed, may be written, if x is measured from the right abutment,

$$DE = \frac{k}{c^2}(2cx - x^2);\ QN = c + x_2 - x_0;\ DN = x_2 + x;\ QG = \frac{k}{c^2}(c^2 - b^2).$$

As $\frac{k}{c^2}$ will be a common factor in the equations which follow, we shall omit it. Substituting these values, we shall get, as the expression to be summed from B to I, for the first condition,

$$\Sigma EK \cdot DE = \int_0^{c+b} \left[\frac{c + x_2 - x_0}{c^2 - b^2}(4c^2x^2 - 4cx^3 + x^4) - (x_2 + x)(2cx - x^2)\right] dx.$$

If x is measured from the left abutment, L Q substituted for Q N, and x_1 written for x_2, we get an expression which is applicable from A to I, or

$$\Sigma EK \cdot DE = \int_0^{c-b} \left[\frac{c + x_1 + x_0}{c^2 - b^2}(4c^2x^2 - 4cx^3 + x^4) - (x_1 + x)(2cx - x^2)\right] dx.$$

As in § 114, these two expressions will be equated to make the change of span zero, and upon performing the indicated integrations, and multiplying through by $c^2 - b^2$, we obtain

$$\begin{aligned}(c + x_2 - x_0)&\left[\tfrac{4}{3}c^2(c+b)^3 - c(c+b)^4 + \tfrac{1}{5}(c+b)^5\right] - (c^2 - b^2)\left[c x_2 (c+b)^2\right. \\ &\left. - \tfrac{1}{3}x_2(c+b)^3 + \tfrac{2}{3}c(c+b)^3 - \tfrac{1}{4}(c+b)^4\right] = (c + x_1 + x_0)\left[\tfrac{4}{3}c^2(c-b)^3\right. \\ &\left. - c(c-b)^4 + \tfrac{1}{5}(c-b)^5\right] - (c^2 - b^2)\left[c x_1 (c-b)^2 - \tfrac{1}{3}x_1(c-b)^3\right. \\ &\left. + \tfrac{2}{3}c(c-b)^3 - \tfrac{1}{4}(c-b)^4\right].\end{aligned}$$

This equation, by reduction and factoring, may be written,

$$\begin{aligned}8c^5x_0 - (c^5 - 5c^3b^2 + 5c^2b^3 - b^5)x_1 + (c^5 - 5c^3b^2 - 5c^2b^3 + b^5)x_2 \\ = 10c^3b^3 - 2cb^5. \quad (1.)\end{aligned}$$

124. **Second and Third Equations of Condition.** — The second condition, that the change of inclination at the abutments shall equal zero, is $\Sigma EK = 0$, and the portion of this expression from B to I will be,

$$\Sigma EK = \int_0^{c+b} \left[\frac{c + x_2 - x_0}{c^2 - b^2}(2cx - x^2) - (x_2 + x)\right] dx,$$

while from A to I we may write, as just explained,

$$\Sigma\,\mathrm{E\,K} = \int_0^{c-b} \left[\frac{c + x_1 + x_0}{c^2 - b^2}(2\,c\,x - x^2) - (x_1 + x)\right] d\,x.$$

Equating, integrating, and reducing, we get

$$(c + x_2 - x_0)\,[c\,(c+b)^2 - \tfrac{1}{3}(c+b)^3] - (c^2 - b^2)\,[x_2\,(c+b) + \tfrac{1}{2}(c+b)^2]$$
$$= (c + x_1 + x_0)\,[c\,(c-b)^2 - \tfrac{1}{3}(c-b)^3]$$
$$- (c^2 - b^2)\,[x_1\,(c-b) + \tfrac{1}{2}(c-b)^2];$$

or

$$4\,c^3\,x_0 - (c^3 - 3\,c\,b^2 + 2\,b^3)\,x_1 + (c^3 - 3\,c\,b^2 - 2\,b^3)\,x_2 = 4\,c\,b^3. \quad (1.)$$

In writing the third condition, that the abutment deflection shall equal zero, or $\Sigma\,\mathrm{E\,K}\,.\,\mathrm{D\,B} = 0$, we must, if we use the values of E K already adopted, make D B equal to x on the right of I, and equal to $2\,c - x$ on the left of I. We then have, from B to I,

$$\int_0^{c+b} \left[\frac{c + x_2 - x_0}{c^2 - b^2}(2\,c\,x^2 - x^3) - (x_2 + x)\,x\right] d\,x,$$

and from A to I,

$$\int_0^{c-b} \left[\frac{c + x_1 + x_0}{c^2 - b^2}(4\,c^2\,x - 4\,c\,x^2 + x^3) - (x_1 + x)\,(2\,c - x)\right] d\,x.$$

Equating these two expressions and integrating, we find that

$$(c + x_2 - x_0)\,[\tfrac{2}{3}\,c\,(c+b)^3 - \tfrac{1}{4}(c+b)^4] - (c^2 - b^2)\,[\tfrac{1}{2}\,x_2\,(c+b)^2 + \tfrac{1}{3}(c+b)^3]$$
$$= (c + x_1 + x_0)\,[2\,c^2\,(c-b)^2 - \tfrac{4}{3}\,c\,(c-b)^3 + \tfrac{1}{4}(c-b)^4]$$
$$- (c^2 - b^2)\,[2\,c\,x_1\,(c-b) + \tfrac{1}{2}(2\,c - x_1)\,(c-b)^2 - \tfrac{1}{3}(c-b)^3],$$

which reduces to

$$16\,c^4\,x_0 - (7\,c^4 - 18\,c^2\,b^2 + 8\,c\,b^3 + 3\,b^4)\,x_1 + (c^4 - 6\,c^2\,b^2 - 8\,c\,b^3 - 3\,b^4)\,x_2$$
$$= -2\,c^5 - 4\,c^3\,b^2 + 16\,c^2\,b^3 + 6\,c\,b^4. \quad (2.)$$

From (1.), § 123, and (1.) and (2.) of the present section, we may readily eliminate x_0, obtaining

$$(c^3 - b^3)\,x_1 - (c^3 + b^3)\,x_2 = 2\,c\,b^3,$$

and

$$(c^2 - b^2)\,x_1 + (c^2 - b^2)\,x_2 = \tfrac{2}{3}\,c^3 + 2\,c\,b^2,$$

whence may be deduced the formulæ of § 122.

125. **Formulæ for H_1 and P.** — The values of H_1, H_2, and P, can now be scaled from the stress diagram, which will also give, if preferred, the proportion

$$H_1 : H_2 : H = c + x_1 + x_0 : c + x_2 - x_0 : 2c + x_1 + x_2,$$

or

$$H_1 = H \frac{c + x_1 + x_0}{2c + x_1 + x_2} = H \left[\tfrac{1}{2} + (5c^2 - 3b^2) \frac{b^3}{4c^5} \right] = \tfrac{1}{2} H [1 + \tfrac{1}{2} n^3 (5 - 3n^2)].$$

H_1 will therefore always be greater than $\frac{1}{2}$ H.

Likewise we have, for the vertical component of the abutment reactions,

$$P : H = \frac{k}{c^2}(c^2 - b^2) : 2c + x_1 + x_2,$$

or

$$P = H \,.\, \tfrac{3}{8} k \frac{(c^2 - b^2)^2}{c^5} = \tfrac{3}{8} H \frac{k}{c}(1 - n^2)^2.$$

The shear diagram for this case will follow the explanation given in § 118.

126. **Circular Arch fixed at Ends.** — There remains to be considered the circular rib, fixed at the ends, under the action of an external horizontal force. The notation of the angles is the same as that previously used for the circular arch. As H is here applied at a point on the right side, x_0, measured from the middle of the span, will now lie on the left of the centre O. Then we will prove that

$$x_1 = \left[\frac{f}{a} - \frac{ab - de}{ac} \left(\frac{f}{a} + \sin\beta \right) \right] r; \quad (1.)$$

$$x_2 = \left[\frac{f}{a} + \frac{ab - de}{ac} \left(\frac{f}{a} + \sin\beta \right) \right] r; \quad (2.)$$

in which equations

$$a = \cos\alpha - \cos\beta, \qquad d = \beta\sin\alpha - \alpha\sin\beta,$$
$$b = \alpha\beta - \sin\alpha\sin\beta, \qquad e = 1 - \cos\alpha\cos\beta,$$
$$c = \beta^2 - 2\sin^2\beta + \beta\sin\beta\cos\beta, \qquad f = \beta - \cos\alpha\sin\beta.$$

It will be noticed that c is constant for a given arch. The value of x_0 can then be obtained from the equation

$$2(\sin\beta - \beta\cos\beta)\,x_0 - [\sin\beta + \sin a - (\beta + a)\cos a]\,x_1 + [\sin\beta - \sin a - (\beta - a)\cos a]\,x_2 = 2\,r\sin\beta\,(\sin a - a\cos a). \quad (3.)$$

The distance x_1 and x_2 will, in every case, be laid off outwards from the abutments, and x_0 will be plotted away from the side where the force is applied. In these formulæ, x_1 is on the opposite side of the arch from the applied force, as is also H_1. In any case it is easy to distinguish between numerical values of x_1 and x_2, or H_1 and H_2, if we notice that the larger value belongs to the abutment which is nearer to the point of application of the external force.

Several of the equilibrium polygons have been drawn in Fig. 39 for a horizontal force applied at different distances from the crown. The angle β of this rib is 60°; and the computed values of the abscissæ, for H at points distant 10° successively from one another, are

a.	x_1.	x_0.	x_2.
10°	.3704 r	.0186 r	.4212 r
20	.4755	.0762	.5860
30	.5892	.2547	1.0345
40	.7291	.5950	2.1559
50	.8749	1.1339	5.9953

127. **First Equation of Condition.** — The processes to be followed are akin to those already given: although the work is somewhat more tedious, it presents no difficulty. As in § 123, we shall find that, Fig. 39, $EK = RN - DN = \dfrac{DE \cdot QN}{QG} - DN$. In the usual notation

$$DE = r(\cos\theta - \cos\beta), \qquad QN = r\sin\beta + x_2 + x_0,$$
$$QG = r(\cos a - \cos\beta), \qquad DN = r\sin\beta + x_2 - r\sin\theta.$$

We therefore have

$$EK = \frac{r\sin\beta + x_2 + x_0}{\cos a - \cos\beta}(\cos\theta - \cos\beta) - (r\sin\beta + x_2 - r\sin\theta)$$

on the right of I. Upon the left of I, since E′K now equals D′L — RL, this expression will change in sign; and, since we measure from L, we must substitute x_1 in place of x_2, must subtract x_0 in place of adding it, and must change the sign of $r \sin \theta$: hence, on the left of I,

$$\text{EK} = -\frac{r \sin \beta + x_1 - x_0}{\cos a - \cos \beta} (\cos \theta - \cos \beta) + (r \sin \beta + x_1 + r \sin \theta).$$

The first condition, invariability of span, will now give,

$$\Sigma_a^{\beta} \text{EK} \,.\, \text{DE} + \Sigma_{-\beta}^{a} \text{EK} \,.\, \text{DE} = 0,$$

or, multiplying by $\cos a - \cos \beta$,

$$\begin{aligned} r\int_a^{\beta} [& (r \sin \beta + x_2 + x_0)(\cos^2 \theta - 2 \cos \theta \cos \beta + \cos^2 \beta) \\ & - (\cos a - \cos \beta)(r \sin \beta + x_2 - r \sin \theta)(\cos \theta - \cos \beta)] \, d\theta \\ & + r\int_{-\beta}^{a} [(r \sin \beta + x_1 - x_0)(-\cos^2 \theta + 2 \cos \theta \cos \beta - \cos^2 \beta) \\ & + (\cos a - \cos \beta)(r \sin \beta + x_1 + r \sin \theta)(\cos \theta - \cos \beta)] \, d\theta = 0. \end{aligned}$$

The integration is similar to that already given for the circular rib in the earlier sections. There results, upon bringing together common factors,

$$\begin{aligned} (\beta & - 3 \sin \beta \cos \beta + 2 \beta \cos^2 \beta) x_0 - (\tfrac{1}{2} \beta + \tfrac{1}{2} a - \tfrac{1}{2} \sin \beta \cos \beta - \tfrac{1}{2} \sin a \cos a \\ & - \sin a \cos \beta - \cos a \sin \beta + \beta \cos a \cos \beta + a \cos a \cos \beta) x_1 \\ & + (\tfrac{1}{2} \beta - \tfrac{1}{2} a - \tfrac{1}{2} \sin \beta \cos \beta + \tfrac{1}{2} \sin a \cos a + \sin a \cos \beta - \cos a \sin \beta \\ & + \beta \cos a \cos \beta - a \cos a \cos \beta) x_2 = r \sin \beta (a - \sin a \cos a - 2 \sin a \cos \beta \\ & + 2 a \cos a \cos \beta). \quad (1.) \end{aligned}$$

128. **Second and Third Equations of Condition.** — The second condition, that $\Sigma_a^{\beta} \text{EK} + \Sigma_{-\beta}^{a} \text{EK} = 0$, similarly gives,

$$\begin{aligned} \int_a^{\beta} & [(r \sin \beta + x_2 + x_0)(\cos \theta - \cos \beta) - (\cos a - \cos \beta)(r \sin \beta + x_2 - r \sin \theta)] d\theta \\ & + \int_{-\beta}^{a} [(r \sin \beta + x_1 - x_0)(-\cos \theta + \cos \beta) \\ & + (\cos a - \cos \beta)(r \sin \beta + x_1 + r \sin \theta)] \, d\theta = 0. \end{aligned}$$

From this equation we obtain, by integrating and factoring,

$$\begin{aligned} (2 \sin \beta - 2 \beta \cos \beta) x_0 - (\sin \beta + \sin a - \beta \cos a - a \cos a) x_1 \\ + (\sin \beta - \sin a - \beta \cos a + a \cos a) x_2 = r \sin \beta (2 \sin a - 2 a \cos a). \quad (1.) \end{aligned}$$

The third condition, that $\Sigma_{a}^{\beta} \mathrm{E\,K} \cdot \mathrm{D\,B} + \Sigma_{-\beta}^{a} \mathrm{E\,K} \cdot \mathrm{D\,B} = 0$, will give, when we introduce the value of $\mathrm{D\,B} = r(\sin\beta - \sin\theta)$,

$$
\begin{aligned}
r\int_{a}^{\beta} &[(r\sin\beta + x_2 + x_0)(\cos\theta - \cos\beta)(\sin\beta - \sin\theta) \\
&- (\cos a - \cos\beta)(r\sin\beta + x_2 - r\sin\theta)(\sin\beta - \sin\theta)]\,d\theta \\
&+ r\int_{-\beta}^{a}[(r\sin\beta + x_1 - x_0)(-\cos\theta + \cos\beta)(\sin\beta - \sin\theta) \\
&+ (\cos a - \cos\beta)(r\sin\beta + x_1 + r\sin\theta)(\sin\beta - \sin\theta)]\,d\theta = 0.
\end{aligned}
$$

Operating upon this equation also, we find that

$$
\begin{aligned}
(2\sin^2\beta &- 2\beta\sin\beta\cos\beta)\,x_0 - (\sin^2\beta + \sin a\sin\beta - \tfrac{1}{2}\cos^2\beta - \tfrac{1}{2}\cos^2 a \\
&+ \cos a\cos\beta - \beta\cos a\sin\beta - a\cos a\sin\beta)\,x_1 + (\sin^2\beta - \sin a\sin\beta \\
&+ \tfrac{1}{2}\cos^2\beta + \tfrac{1}{2}\cos^2 a - \cos a\cos\beta - \beta\cos a\sin\beta + a\cos a\sin\beta)\,x_2 \\
&= r\sin\beta\,(2\sin a\sin\beta - \cos^2 a + \cos a\cos\beta - 2\,a\cos a\sin\beta) \\
&+ r\beta\,(\cos a - \cos\beta). \qquad (2.)
\end{aligned}
$$

129. **Reduction.** — From (1.), § 127, and (1.) and (2.), § 128, we can determine the desired quantities x_0, x_1, and x_2, by any of the usual steps for elimination. If the second equation of condition is multiplied by $\sin\beta$, and then subtracted from the third, there will result

$$
\begin{aligned}
(\tfrac{1}{2}\cos^2\beta - \cos a\cos\beta + \tfrac{1}{2}\cos^2 a)\,(x_1 + x_2) \\
= r\sin\beta\,(\cos a\cos\beta - \cos^2 a) + r\beta\,(\cos a - \cos\beta),
\end{aligned}
$$

which, upon being divided by $\tfrac{1}{2}(\cos a - \cos\beta)$, becomes

$$(\cos a - \cos\beta)(x_1 + x_2) = 2r(\beta - \cos a\sin\beta). \qquad (a.)$$

Again: the second equation may be multiplied by $\cos\beta$, and added to the first, after which the values of x_0 from the new equation and from the second equation of condition may be equated. If we then clear of fractions, and factor the resulting equation, it may be written

$$[a(b-c) - de]\,x_2 + [a(b+c) - de]\,x_1 = -2r\sin\beta\,(ab - de), \qquad (b.)$$

while equation $(a.)$ will be

$$a(x_1 + x_2) = 2fr; \qquad (c.)$$

in which equations the literal coefficients stand for the quantities already given in § 126.

From (*b.*) and (*c.*) it is easy for one to obtain the half sum and the half difference of the two unknown quantities, and thence equations (1.) and (2.), § 126. Equation (3.) is identical with (1), § 128.

130. **Formulæ for H_1, &c.; Semicircular Arch.** — To find the values of H_1, H_2, and P by formula, we make use of similar expressions to those of § 125. The figure gives us

$$H_1 : H_2 : H = r\sin\beta + x_1 - x_0 : r\sin\beta + x_2 + x_0 : 2r\sin\beta + x_1 + x_2;$$

or

$$H_1 = H\frac{r\sin\beta + x_1 - x_0}{2r\sin\beta + x_1 + x_2} = \frac{a}{2r}\cdot\frac{r\sin\beta + x_1 - x_0}{\beta - \sin\beta\cos\beta}H.$$

$$P : H = r(\cos\alpha - \cos\beta) : 2r\sin\beta + x_1 + x_2 = ar : 2r\sin\beta + \frac{2fr}{a};$$

or

$$P = \tfrac{1}{2}\frac{a^2}{a\sin\beta + f}H = \tfrac{1}{2}H\frac{(\cos\alpha - \cos\beta)^2}{\beta - \sin\beta\cos\beta}.$$

If the arch subtends a semicircle, $\beta = \frac{1}{2}\pi$, $\sin\beta = 1$, $\cos\beta = 0$, and the preceding values are much simplified. Without writing them in detail, it will be sufficient to indicate that then

$$a = \cos\alpha, \qquad c = \tfrac{1}{4}\pi^2 - 2, \qquad e = 1,$$
$$b = \tfrac{1}{2}\pi\alpha - \sin\alpha, \qquad d = \tfrac{1}{2}\pi\sin\alpha - \alpha, \qquad f = \tfrac{1}{2}\pi - \cos\alpha.$$

131. **Sign of Bending Moment.** — In determining the sign of the bending moment at any point when the arch is acted upon by a horizontal force, it will be well for the reader to recollect, that, when there is a thrust along any portion of the equilibrium polygon, the arched rib tends to move away from the polygon, but, when there is tension in any portion, the arch moves towards the polygon. This tendency to move in one direction or the other is easily fixed in the mind, if one thinks of the alteration of curvature of a bent wire when a force is applied at each end in the line joining the two ends. The same thing was noticed in the suspended arch of Fig. 1 and in those under vertical forces. Therefore, in Fig. 32 and the following

ribs, the arch tends to approach the tension side of the equilibrium polygon, and to recede from the compression side. If then, as before, that moment which makes any portion of the rib less curved, or which, if exerted on a beam supported at both ends, would make it concave on the upper side, be called positive, the areas of — M will occur between B and C in Figs. 32 and 33, and those of + M will be found between C and A. Ribs fixed at the ends will be strained similarly. In Fig. 38, for example, the area to the right of B will give + M; from the point where N G crosses the rib to C there will be — M, which then changes to + M on the left of C, and to — M, when the polygon crosses the rib above A.

132. **Example of Normal Forces.** — As we have now ascertained the values of the abutment reactions when a rib is acted upon by a horizontal force, we will show, by an example, that the various horizontal and vertical forces which are exerted at one time at different points of the rib may be provided for in one polygon, without the necessity for separate treatment of the horizontal and vertical components into which the normal or oblique external forces can be decomposed. We will suppose that a parabolic rib of 100 feet span and 50 feet rise is to be used as a principal to carry a roof, and that it is desired to ascertain the bending moments arising from the action of the wind upon one side. We will take the case where the rib is fixed at the ends as being less simple. After this discussion, the reader will have no difficulty in applying a similar treatment to other ribs.

Let the rib be represented by A C B, Fig. 40, and let us suppose that the normal wind pressure is directly resisted by the flanges and bracing of the rib at points D, E, F, and G, at which purlins rest, and which are distant 40 feet, 30 feet, 20 feet, and 10 feet horizontally from the middle of the span. The amount of the pressure N_2 at E will be the total or resultant of the distributed pressure on *m n*, the points *m* and *n* being taken midway of the spaces on each side of E. There will be no error of consequence in assuming that the wind pressure on *m n* is

perpendicular to the straight line $m\,n$, or to the tangent of the parabola at E.* To find this tangent, draw E E′ horizontally, make C E′′ = C E′, and E E′′ will be the desired tangent. The tangents at the other points are found in the same way. The angle E′ E E′′ is very nearly 50°; the intensity of wind pressure, by the table of § 109, is 38 pounds on the square foot of roof; and if the principals are 10 feet apart, and $m\,n$ is $15\frac{1}{2}$ feet, the total normal force N_2 at this point will be $38 \times 10 \times 15\frac{1}{2} =$ 5,890 pounds. For the four points we therefore find in detail

						N.	V.	H.
1	58°	40 ×	19 ×	10 =		7,600 lbs.	4,000 lbs.	6,400 lbs.
2	50	38	$15\frac{1}{2}$	10		5,890	3,800	4,500
3	$38\frac{1}{2}$	32	13	10		4,160	3,200	2,600
4	22	20	11	10		2,200	2,000	900

These normal forces are plotted on the figure, and then decomposed graphically into their vertical and horizontal components, which, scaled to the nearest one hundred pounds, are found above in the columns headed V and H. The figure and diagrams are drawn to scales of forty feet and ten thousand pounds equal one inch.

133. **Finding the Reactions.** — The next step will be to find the values of H_1, H_2, P_1, and P_2, for the above forces. First, upon referring to § 64, we see that a vertical force at E, Fig. 40, 0.6 c from the middle of the span, will cause a vertical reaction of 0.896 V at A, one of 0.104 V at B, and will give rise to H, at each abutment, of the amount $0.192\,\frac{c}{k}\,V = 0.192\,V$. We also see, by the table of § 62, that the ordinate at A will be $-0.667\,k$, and at B $+0.333\,k$, for the same force at E; and we can then obtain the values of M at the abutments arising from V by multiplying these ordinates by $H = 0.192\,V$, just ascertained. The computations for the four loaded points may be grouped together as follows:

* If preferred, analyze the wind pressures as in Part I., Roofs, p. 44.

	V.		P₁.		H.
1	4,000 $\times$ 0.972 =		3,888 lbs.	V $\times$ .0607 =	243 lbs.
2	3,800	0.896	3,405	.1920	730
3	3,200	0.784	2,509	.3308	1,059
4	2,000	0.648	1,296	.4320	864
	13,000		$P_1' =$ 11,098 lbs.		$H' =$ 2,896 lbs.

$V =$ 13,000
$P_1' =$ 11,098
$P_2' =$ 1,902 lbs.

	H.	y_1.	M₁.	y_2.	M₂.
1	243 $\times$	$-2.000\ k$ =	$-24,300$ ft. lbs.	$0.370\ k$	$+$ 4,495 ft. lbs.
2	730	-0.667	$-24,333$	0.333	12,167
3	1,059	-0.222	$-11,767$	0.286	15,144
4	864	0.000	000	0.222	9,600
	Totals . . .		$M_1' = -60,400$ ft. lbs.		$M_2' = +41,406$ ft. lbs.

It is to be understood that y_1, P_1, and M_1 refer to the left abutment, the others, to the right abutment.

From § 122 and § 125 we now compute the reactions from the horizontal forces at the four loaded points, and the accompanying bending moments:

	H.		$\pm$ P.		
1	6,400 $\times$	.0486 =	311 lbs.	H $\times$ 0.894 =	5,722 lbs.
2	4,500	.1536	691	0.712	3,204
3	2,600	.2646	688	0.572	1,487
4	900	.3456	311	0.510	459
	14,400				

$H =$ 14,400
$H_1' =$ 10,872
$H_2' = +$ 3,528 lbs.

Totals, P′ from H's $= \pm$ 2,001 lbs. $H_1' = -10,872$ lbs.

	P.	x_1.	M₁.	x_2.	
1	311 $\times$	$4.600\ c$ =	$-71,530$ ft. lbs.	$0.807\ c$	$+$ 12,549 ft. lbs.
2	691	1.533	$-52,976$	0.633	21,870
3	688	0 689	$-23,702$	0.486	16,718
4	311	0.400	$-$ 6,220	0.378	5,878
	Totals		$M_1' = -154,428$ ft. lbs.		$M_2' = +57,015$ ft. lbs.

The final abutment moments will be

$$M_1' = -60{,}400 - 154{,}428 = -214{,}828 \text{ ft. lbs.}$$

$$M_2' = 41{,}406 + 57{,}015 = +98{,}421 \text{ ft. lbs.}$$

The components of the reaction at A are, if thrusts are considered positive,

$$P_1' = P_1 - P = 11{,}098 - 2{,}001 = +9{,}097 \text{ lbs.}$$

$$H_1' = H + H_1 = 2{,}896 - 10{,}872 = -7{,}976 \text{ lbs.}$$

The components at B will be

$$P_2' = P_2 + P = 1{,}902 + 2{,}001 = +3{,}903 \text{ lbs.}$$

$$H_2' = H + H_2 = 2{,}896 + 3{,}528 = +6{,}424 \text{ lbs.}$$

The arrows at A and B show these reactions. If the rib consists of chords and bracing, the stresses on the pieces can be found by a diagram like Fig. 21, Part I., "Roofs," care being taken to have the stresses in the two flanges at the abutment give the proper reaction (see § 195). If the equilibrium polygon is to be drawn, from which to find bending moments and chord stresses, we need the point of beginning for the polygon.

The abscissa, or ordinate to the equilibrium polygon at A, will be found by dividing the total M at that point by P_1' or H_1'; and similarly for the abutment B; thus,

$$x_1' = \frac{-214{,}828}{+9{,}097} = -23.6 \text{ ft.} \qquad x_2' = \frac{+98{,}421}{+3{,}903} = +25.2 \text{ ft.}$$

$$y_1' = \frac{-214{,}828}{-7{,}976} = +27.0 \text{ ft.} \qquad y_2' = \frac{+98{,}421}{+6{,}424} = +15.3 \text{ ft.}$$

As in previous examples, the ordinate at one abutment alone is needed; but the others are useful as a check on the accuracy of the drawing.

134. **Equilibrium Polygon; Bending Moments.** — We may now proceed to draw the stress diagram. Lay off 1–2, 2–3, 3–4 and 4–5, parallel successively to the external forces at G, F, E,

and D, and equal to the calculated amounts by any desirable scale; make 5–6 $= H_1'$, and 6–0 $= P_1'$, so that 5–0 shall represent the reaction at A in the proper direction as expressed by the signs obtained above, P_1' being a compression, and H_1' a tension; finally, lay off 0–7 $= P_2'$, and 7–1 $= H_2'$, giving 0–1 for the reaction at B. The closing of 0–1 on the point 1 proves that the diagram has been drawn with care. Having drawn B Q $= + y_2'$, or B R $= + x_2'$, draw through Q or R a line parallel to 0–1, as far as O, where it meets the normal force at G. Then draw O L parallel to 0–2, to cut the force N_3 at L. Follow with L K and K I, parallel to 0–3 and 0–4, closing with a line through I, parallel to 0–5, which, if the polygon has been accurately drawn, will make A W $= y_1'$, as recently computed, or A U $= - x_1$.

As neither H nor P is constant for *oblique* forces on an arch, the bending moment at any point will equal the product of the force acting along a side of the polygon just drawn multiplied by the perpendicular from the point to the side: thus the bending moment at E is E S $\times$ (0–3), or E T $\times$ (0–4). If the external forces had been considered as applied at a greater number of points, or as distributed along the principal rafter itself, we should have obtained a polygon which approached nearer to a regular curve, and such a curve has been sketched through the vertices of the polygon just drawn.

135. **Equilibrium Polygons for the Vertical and Horizontal Components.** — Since most of the needful data have already been obtained, we have thought it expedient to draw the equilibrium polygons for the vertical and horizontal components separately, so that they may be compared with each other and with the polygon for normal forces. If a horizontal and a vertical line are drawn from 1 and 5, the components H and V can be at once projected upon them. Upon laying off H_1, and plotting P, we shall locate the pole 0″; and 0″–2″, 0″–3″, &c., will be parallel to the lines of the polygon for horizontal forces. In the same way, P_1 and H for vertical forces will determine 0′. The value of y_2 will be found, upon dividing the M_2 which

comes from V by H, to be 14.3 feet, giving the starting-point just below Q. Upon drawing the polygon so that the angles are made at the verticals through the loaded points, we obtain the broken line which finally runs below A. This ordinate y_1 may be verified. If M_2 from the H's is divided by P, we have $x_2 = 28.5$ feet, an ordinate a little longer than B R. The polygon, if now drawn, will be the broken line which passes near E′, and extends to a considerable distance, 77.2 feet, to the left of A. All the sides of this polygon except the first are in tension.

136. **Shear and Direct Stress.** — To complete this example, the normal shear at the middle of each division is found, and at the same time the direct stress. The small letters *l*, *m*, *n*, &c., mark the middle of each division. Draw 0–*l* in the stress diagram, parallel to the tangent at *l* in the rib, and 5–*l* perpendicular to it; then will 5–*l* be the normal shear at *l*, and *l*–0 the direct thrust. To satisfy ourselves in regard to the sign of this shear, we note that 5–0 is the thrust in the side U I of the equilibrium polygon, and will therefore be the resultant force on the left of any section between A and D; the forces 5–*l* and *l*–0, in the directions named, will be its components, also on the left of the section *l*: hence we have *positive* shear and a direct thrust. In the same way at *m*, since 4–0 is the thrust in I K, 4–*m* will be the positive shear, and *m*–0 the direct thrust. Between *m* and *n* the shear changes sign; for at *n* we find 3–*n* and *n*–0, the former being drawn *down*, instead of *up*. Passing on, we see that the shear again changes between *r* and *s*, because 1–*r* and 1–*s* run in opposite directions. As noted before, this change of sign occurs at points of maximum bending moment.

137. **Vertical Shear Diagram.** — We may draw a vertical shear diagram, if desired, and from that obtain the normal components; but it is not so conveniently constructed in the case of several forces which are always applied together as for a case of a single load. If *a b* represents the span, P_1' or 6–0 is laid off at *a w*, upwards as usual; then the subtraction of V_1 at D, or 4′–5, brings us to the line *d*; thence a step is made to *e*, to *f*, and finally to *g*, closing at *b* with 0–7, the reaction at B. The horizontal line below *a b* cuts off P, or 0″–3″, so that the vertical components shown in the line 5–1′

might be considered as laid off from this lower line, and the constant quantity P, due to the horizontal components, then subtracted. As the thrust at B is 0–1, a line drawn through 0, parallel to the tangent at B, will cut off from a vertical line drawn from 1 as much vertical force as is required, in addition to 0–7, to give a resultant in the direction of the rib at B. The amount so determined is laid off at $q' r'$. Since it has been shown that all inclined lines are drawn towards the middle of the span c, and are uninterrupted until an external force is encountered, we draw through c the line $r' c s$.

In a similar way, a line 0–10 from 0, parallel to the tangent at A, will cut the vertical through 5 at a distance 5-10, equal to $w u$; a line from 0, parallel to the tangent at D, will cut off the distance from a vertical through 4, which is plotted from d to k; one parallel to the tangent at E will cut off 3–8, which is plotted at $e o$; and the tangent at F gives 0–9, so that 2–9 is laid off at $f p$. If inclined lines are drawn through the points thus found, running towards the point c, the diagram will be completed. Normal components of the ordinates between the two sets of lines just constructed, measured above l, m, n, &c., will agree with the values of the last section, —positive when above the inclined lines, negative when below.

CHAPTER IX.

STONE ARCHES.

138. **Location of Equilibrium Curve determines Thickness of Voussoirs.** — Stone arches may be treated as belonging to the class of ribs with fixed ends, as the voussoirs have sufficient breadth at the skew-backs to make a firm bearing. We can, then, for a given rise, span, and distribution of steady and travelling load, draw the equilibrium curve, and thence determine the required thickness of the arch-ring. To repeat what was mentioned incidentally earlier: if no reliance is placed upon the tenacity of the cement, and if the intensity of pressure at a joint between any ~~two voussoirs~~ or arch-stones is considered to vary uniformly from the outside to the inside edge, the extreme case of deviation of the resultant pressure from the middle of the joint consistent with safety will occur when the pressure is zero at one edge. As the varying intensity of pressure will be represented by the ordinates to an inclined line which passes through the point where the pressure is zero, the total pressure will be equal to the area of a triangle, and the resultant will pass through the centre of gravity of the triangle, or at a distance of one-third the breadth of the ring from that edge where the pressure is most intense. Since the equilibrium curve is the locus of the resultant force at each joint, the condition that the pressure shall never be less than zero at any point, or that there shall be no tension, is equivalent to requiring that the equilibrium curve shall never pass beyond the middle third of the

arch-ring, however the distribution of the load may be varied: hence, when the equilibrium curves are drawn, the thickness of the voussoirs is readily determined. The tensile strength of the cement after it has become firm, and any deviation from the assumption that the force between two stones must be distributed over the whole joint, increase the safety of the structure, and thus give what is akin to the factor of safety in other cases.

139. **Intensity of Pressure.** — When the stability of the arch-ring is thus assured, it is an easy matter to find the greatest intensity of pressure, and hence to see whether the material proposed for the arch will have strength enough. When the equilibrium curve passes through the centre of the joint, the pressure on the square inch will be found by dividing the thrust at that joint by the area of the bearing surface. If the curve touches the extreme limit, the edge of the middle third, the most intense pressure, at the edge of the joint nearest to the curve, will be twice the mean pressure; for the height of the triangle whose ordinates represent the varying intensities is twice its mean ordinate. In some rare cases, where the span is large, and the stone is of a weak quality, we may have to increase the depth of the arch-ring in order to provide sufficient strength.

140. **Circular Arch; Load for Equilibrium.** — Although the curve of the arch-ring may be any one of a number of forms, the circular arch is the more common type, and we have therefore thought it best to take such an arch as an example of this method: the steps will apply to any form. The Gothic arch will be classed with the example of § 194. If the load is entirely, or almost entirely, steady, as in the aqueduct or canal bridge, it will be advisable, on the score of economy, to find that distribution of the load which shall cause the equilibrium curve to coincide with the centre line of the arch-ring. Then, by arranging the filling and the empty spaces above the arch-ring so as to conform to that distribution, the voussoirs can be made of moderate depth.

Thus, if B C, Fig. 45, be one-half of an arch which it is desired to load in this way, divide it, by vertical lines, into quite a large number of parts, equal horizontally. If the divisions are small, the areas of these portions between the soffit of the arch and the upper line may be considered trapezoids, and the middle ordinate of each division will be proportional to its volume for unity of thickness, and to its weight, if homogeneous. It is then evident, that, if there is to be no bending moment at any point, the equilibrium curve must coincide, either with the tangents to the centre line of the ring at these loaded points, or with the chords drawn between these points, according as the first loaded point is taken at half a division's distance from the abutment, or at the abutment itself. See Part II., "Bridges," § 58. Let this weight be concentrated, in imagination, on each middle ordinate.

Upon drawing, from any point 0, radiating lines parallel to the tangents, or perpendicular to the radii, at the successive points of division, and cutting them all by a vertical line 1–12 at any convenient distance, loads in each division, supposed to be concentrated at the intersection of the above tangents,* and proportional to the several portions of the vertical line intercepted by the inclined lines, will be the ones required for equilibrium; and the distributed loads spread over all of each division, or, in other words, a continuous load over the whole arch, will thus be found. If 1–2 is placed at such a distance from 0 that it will represent, by a convenient scale, the mean depth, as well as the weight of the load, in the first division on the right of C, 2–3, 3–4, &c., will represent the required depth of loading in the succeeding divisions. As the angle made by 0–2 with the horizontal line is the same as that subtended at the centre by the first division near C, there is no difficulty in finding, by calculation, the exact length of 0–1, when 1–2 is given, in case the angle at 0 is too acute to give any accurate result graphically. In our figure the depth of the load at the

* The tangents will not intersect exactly in the middle of each division.

crown was assumed to be five feet, and the intercepted portions of the vertical line were then plotted from the points where verticals at the middle of each division would cut the centre line of the arch. The curved line drawn through the upper ends of these ordinates will then show the desired amount of homogeneous load to be spread over the arch to produce equilibrium.

141. **Limiting Angle for Arch-Ring without Backing.** — It is now worthy of notice, that, while the required depth of loading increases but slowly for some distance after we leave the crown, when we reach the haunches, the ordinates rapidly lengthen, and the curve through their upper ends will finally become vertical, if the arch springs vertically from the abutment. This point was also referred to in § 89. It is apparent, therefore, that it is not practicable to so load with vertical forces a circular arch, beyond a certain distance from the crown, that the line of thrust shall coincide with the centre line of the arch-ring. As the roadway must not deviate greatly from a horizontal line, we see, that, for an arch extending 60° each way from the crown, the amount of material as heavy as masonry required over the springing will fill all of the available space, and, when the spandrel filling is lighter, the limiting angle will probably be in the neighborhood of 45°. In ordinary cases of loading, the equilibrium curve will deviate so much from the centre line in this portion of the rib as to require very deep voussoirs to retain the curve within the middle third when the attempt is made to extend the unassisted arch-ring much farther. It is customary, therefore, to carry the masonry backing, in horizontal courses, up to the neighborhood of the point where the arch-ring is inclined at an angle of 45°: below this point any attempt of the arch-ring to move outwards under the thrust of the upper portion is immediately resisted by the backing, and the arch will be designed as if the springing points were at the joints level with the top of this masonry backing. The portion below really forms a part of the abutment.

142. **Example; Data.** — In accordance with the above statements, and as an example of the application of preceding principles, we propose to design a circular segmental arch of stone, for a railroad bridge, which shall subtend 100°, with a radius, for the centre line of the voussoirs, of 100 feet, making the span, from centre to centre of skew-backs, about 153 feet, and the rise about 36 feet. The rolling load will be 3,000 pounds per running foot of track, and the width of the bridge over which this load is distributed will be ten feet. The backing will be carried up to the point where the rib is inclined at 45°, and the remainder of the spandrel will be filled with such material, or will have such an amount and distribution of empty spaces, that it shall weigh, on the average, one-half as much per cubic foot as does the masonry of the arch-ring. The equilibrium curve for steady load will now first be found; then such possible combinations of rolling load will be discussed as will increase the deviation of the steady load curve at those points where it already deviates most from the centre line of the arch-ring; and, finally, the necessary depth of the voussoirs will be determined by the rule suggested in § 138. The depth of the voussoirs at the crown is assumed, in our present ignorance of the final dimensions, at five feet; two feet of filling, earth or some other material, is added at that point, and the horizontal line drawn seven feet above the soffit at the crown will be the upper boundary of the spandrel filling. If, then, the arch-ring is taken at a uniform thickness of five feet, as shown at A C, on the left half of Fig. 45, the depth of a homogeneous load equal to stone will be found by shortening each ordinate above the arch ring one-half. Thus was obtained the curve D E. By dividing the area between this curve and the soffit into small portions by vertical lines, we may find the weight to be concentrated on the several assumed loaded points of the arch-ring.

143. **Calculations for Steady Load.** — From the equations of § 92, after making $\beta = 45°$, and giving to α the successive values, 5°, 10°, 15° . . . 40°, we have worked out the quantities y_1, y_0, and y_2, for a weight at such distances from the crown, and

these quantities are given in the first portion of the following table, it being understood that the weights are here placed on the left of the crown to correspond with our figure: —

α.	y_1.	y_0.	y_2.	H.	P_1.	P_2.
0°	.0449 r	.3587 r	.0449 r	1.126 W	.5 W	.5 W
5	.0252	.3585	.0607	1.095	.596	.411
10	.0001	.3578	.0735	1.007	.683	.325
15	—.0341	.3569	.0842	0.866	.760	.244
20	—.0817	.3555	.0930	0.690	.830	.172
25	—.1536	.3537	.1012	0.498	.890	.111
30	—.2730	.3515	.1078	0.311	.939	.063
35	—.5137	.3487	.1142	0.150	.972	.027
40	—1.2407	.3470	.1183	0.040	.993	.007

These values of y_1, y_0, and y_2, have been plotted on the arch of Fig. 44, and the several stress diagrams have been drawn on a vertical line which represents W. From this figure the amounts of H and of the vertical components of the abutment reactions for a load W at successive points can be scaled off, and thus we obtain the last three columns of the above table. H, P_1, and P_2, can also be easily calculated by the formulæ of § 63, if we make $c = r \sin \beta$, and $b = r \sin \alpha$.

Having divided the centre line C A of the arch-ring of Fig. 45 at points C, F, G, &c., distant five degrees from one another, the weight to be concentrated at each of these loaded points is next computed, for an arch one foot thick, perpendicular to the plane of the paper, by scaling the area between the dotted ordinates, marked on the horizontal line, and placed midway between the points of division, and multiplying this area by the weight of a cubic foot of masonry, here assumed at 150 pounds. The weights at the several points, to the nearest hundred pounds, will then be

C = 7,500, F = 7,600, G = 8,400, I = 9,600, K = 11,100,
L = 12,800, N = 14,600, O = 16,600 P = 19,300 lbs.

making the weight of the half-arch (when we take one-half of the load at C, and add 9,800 pounds for the load at A), = 113,-450 pounds.

Calculate H for steady load by multiplying each co-efficient of H in the table above by its W in pounds just ascertained, and adding all the results for both halves of the arch. The work in detail is below. As the two halves of the arch are alike, we add up the column for H, add in again all but the amount for the load at the crown, and have H′ for the entire arch. Each vertical reaction will equal the weight of the half arch.

To find the ordinate $y_1' = y_2'$, for the combined weights, multiply each H by its y_1, add the products, and divide by H′. As, for each weight on one half of the arch, there will be a corresponding and equal weight on the other half, it will shorten the process to add y_1 and y_2 together for each point on one-half of the rib, *except the centre one* at C.

			W.	H.	$y_1 + y_2$.	M_1.	
C.	0°	1.126 ×	7,500 =	8,445 lbs.	.045 r	+ 380.0 r lbs.	
F.	5	1.095	7,600	8,322	.086	715.7	
G.	10	1.007	8,400	8,459	.074	626.0	
I.	15	0.866	9,600	8,314	.050	415.7	
K.	20	0.690	11,100	7,659	.011	84.2	
L.	25	0.498	12,800	6,374	—.053		—337.8 r lbs.
N.	30	0.311	14,600	4,541	—.165		749.2
O.	35	0.150	16,600	2,490	—.400		996.0
P.	40	0.040	19,300	772	—1.123		867.0
				55,376 lbs.		+ 2,221.6	—2,950.0
				46,931		— 2,950.0	
			H′ =	102,307 lbs.	) —728.4 × 100 (	—.712 ft. = y_1'.	

144. Equilibrium Curve for Steady Load. — Plot the weights of the above table on a vertical line from 1′ to 10′, lay

off H' from the middle of $1'$–$2'$ to $0'$, and, starting at 0.71 feet below A, draw an equilibrium polygon with its sides successively parallel to the lines which would radiate from $0'$. This polygon will run quite close to the centre line, crossing it twice between A and C, and passing 0.4 feet below it at the crown. In any actual example the whole polygon should be drawn, as its accuracy will be proved by its striking the ordinate from B at the proper distance. If this arch were never to be subjected to any other than a steady load, or should the travelling load always be light, voussoirs of moderate depth would contain this polygon within their middle third. The true equilibrium curve will pass through the angles of the polygon just drawn.

145. **Calculations for Rolling Load.** — But, as we stated that a line of railroad was to be carried over this arch, let us suppose that the rolling load of one ton and a half per foot of track, or 3,000 pounds, is distributed over the ten feet of width of the arch; the moving load will then amount to 300 pounds per foot of span on the rib of our figure. The sleepers, the filling over the rib, and the bond of the arch-stones, will distribute any concentrated load over a considerable area.

At the crown of the arch the curve already drawn falls somewhat below the centre line. Upon inspecting Fig. 44 we see that six of the polygons there drawn pass below the crown of the rib. If, therefore, we place upon the stone arch a rolling load which covers six points of division from each abutment, that is, from Q to R on one side, and a corresponding distance on the other half arch, this distribution of load, if a practicable one under the usual method of running trains, will cause the greatest deviation of the equilibrium curve at the crown C.

To draw the polygon for this rolling load alone: first multiply each horizontal distance belonging to I, K, L, &c., by 300 pounds, to obtain the concentrated load on each point; then multiply by the proper co-efficients of H already obtained; sum the products, and double the results for both halves of the arch; multiply each H by its y_1 and y_2; divide the algebraic

sums of these products by H″. The operations are carried out below.

		W.		H.	$y_1 + y_2$.		
I.	8.4	2,520 ×	.866 =	2,182	.050	+ 109.1 r lbs.	
K.	8.2	2,460	.690	1,697	.011	18.7	
L.	7.9	2,370	.498	1,180	—.053		— 62.6 r lbs.
N.	7.5	2,250	.311	700.	—165		115.4
O.	7.1	2,130	.150	320.	—400		127.8
P.	6.7	2,010	.040	80	1.123		90 0
		13,740		6,159		+ 127.8	— 395.8

H″ = 12,318) — 268.0 × 100 (— 2.2 ft. = y_1''.

Lay off the loads for one-half of the rib on a vertical line from 4″ to 10″; make 4″– 0″ = H″; and, laying off $y_1'' = -2.2$ feet, at A, draw the polygon which passes horizontally below C at a distance, by scale, of 2.3 feet.

146. **Increase of Bending Moment at Crown; Required Depth of Keystone.** — We can now find how much this added load increases the negative bending moment at the crown of the rib, or how much it causes the equilibrium curve to move inwards. If we multiply H′ and H″ by the ordinates to their respective curves at the crown, which ordinates are 0.4 feet and 2.3 feet, as lately stated, and add the products, we shall obtain the existing moment at the crown, and, upon dividing by H′ + H″, we get the ordinate from the centre line at C to the curve for the combined loads. It is worthy of note how little effect the rolling load produces, owing to the great thrust of the masonry itself.

102,307 × 0.4 =		40,922.8 ft. lbs.
12,318 × 2.3 =		28,331.4
114,625		)69,254.2
Ordinate at C =		0.60 ft.

In order that this deviation of 0.6 feet from the middle of the joint shall not bring the equilibrium curve outside of the

middle third, the keystone and adjoining voussoirs must not be less than $0.6 \times 6 = 3.6$ feet deep. The greatest intensity of pressure, found at the inner edge, will then be twice the mean intensity of pressure, or $2\,[114{,}625 \div (3.6 \times 144)] = 442$ pounds per square inch, giving a factor of safety against crushing of about ten, for good limestone or sandstone. If the depth of the joint be increased to *four* feet, the greatest intensity of pressure at the inner edge will be reduced to $\frac{4 + 3.6}{4} \cdot \frac{114{,}625}{4 \times 144} = 378$ lbs. per square inch.

147. Increase of Bending Moment at Haunch. — The steady load curve deviates outwardly from the centre line the greatest distance, 0.5 feet, at L. Fig. 44 again shows that a rolling load from Q to R of Fig. 45 will increase this deviation to the greatest extent. The value of the horizontal thrust, H''', for this load, will be seen, from the table of § 145, to be 6,159 pounds. Multiplying the same values of H by the then existing values of y_1, and proceeding as usual, we shall obtain y_1'''. If the total M_1 of this table is subtracted from

	H.	y_1.	M_1.	W.		P_2.
I	2,182 ×	—.034 =	— 74.2 *r* lbs.	2,520 ×	.244 =	614.9 lbs.
K	1,697	—.082	—139.2	2,460	.172	423.1
L	1,180	—.154	—181.8	2,370	.111	263.1
N	700	—.273	—191.0	2,250	.063	141.7
O	320	—.514	—164.2	2,130	.027	57.5
P	80	—1.241	— 99.3	2,010	.007	14.1
	6,159 lbs.	)	—849.7 × 100 (—13.8 ft. = y_1'''.			$P_2''' = 1{,}514.4$ lbs.
		)	+581.7 × 100 (+ 9.4 ft. = y_2'''.			

that of the table in § 145, we shall obtain the moment at B, and thence find y_2'''. To obtain the vertical component of one reaction, multiply each load by the proper co-efficient of P_1 or P_2, given in § 143. Since P_2''' is 1,514.4 pounds, lay this amount off from 4'', draw H''' to 0''', and plotting $-\,y_1'''$ at A, and

$+ y_2'''$ at B, draw that equilibrium polygon which passes 7.1 feet above L.

By the same process as before, we find that the equilibrium curve for the steady load, combined with these six loads on the left side of the arch, will be displaced from the centre line vertically at L 0.875 feet. The depth of the arch-ring at this point should, therefore, not be less, vertically, than 5.25, or, measuring normally, than $5.25 \times \cos 25° = 5.25 \times 0.9063 =$ 4.76 feet.

$$\begin{array}{rcl} 102{,}307 \times 0.5 & = & 51{,}153.5 \text{ ft. lbs.} \\ 6{,}159 \times 7.1 & = & 43{,}728.9 \\ \hline 108{,}466 &) & 94{,}882.4 \\ \text{Ordinate at L} & = & 0.875 \text{ ft.} \end{array}$$

148. **Influence of an Additional Load.** — When it is noticed that an additional load on the point G will cause the greatest positive moment at K, it may be suspected that these seven loads will cause a greater deviation at K than the one just found at L. To ascertain the fact, we may dispense with any new polygon by proceeding as follows: The new load G will be $8.6 \times 300 = 2{,}580$ pounds. H for this point, being 1.007 W, will equal $2{,}580 \times 1.007 = 2{,}598$ pounds. By scale, in Fig. 44, the ordinate from the proper polygon to the arch at the point K is $.017\,r = 1.7$ feet. The ordinates to the curves already drawn in Fig. 45 being scaled at K, the annexed computation is readily made, and the quotient is seen to be less than the amount at L. Kindred steps might be taken for any point.

$$\begin{array}{rcl} 102{,}307 \times 0.35 & = & 35{,}807.4 \text{ ft. lbs.} \\ 6{,}159 \times 8.10 & = & 49{,}887.9 \\ 2{,}598 \times 1.70 & = & 4{,}416.6 \\ \hline 111{,}064 & & 90{,}111.9 \end{array}$$

149. **Increase of Bending Moment at Springing; Maximum H.** — The remaining point of maximum deviation of the curve for steady load is at the springing A, where we have found it to be .71 feet. As the same six loads from Q to R will be seen, from Fig. 44, to produce the maximum effect at A, the polygons are already drawn to our hand, and the moments at the springing point are seen in the respective tables. There-

fore the ordinate at A is 1.45 feet, and the normal displacement is $1.45 \times \cos\ 45° = 1.45 \times .707 = 1.03$ feet. The necessary depth for this joint will be 6.2 feet. If the amount of P_1 from rolling load, 12,226 pounds, is laid off below 10′, and H‴, 6,159 pounds, is plotted to the right of 0′, the line connecting the two points thus found will be the thrust at A, and, from its projection on a line inclined at 45°, we get 158,000 pounds for the direct thrust at A. The maximum intensity of compression on this joint will be at the inner edge, and will be $2\ [158{,}000 \div (6.2 \times 144)] = 354$ pounds per square inch.

$$
\begin{array}{llll}
102{,}307 \times & .71 & = & 72{,}840 \\
\underline{\ \ 6{,}159} \times & 13.8 & = & \underline{\ \ 84{,}970} \\
108{,}466 & & &)157{,}810 \\
\text{Ordinate at A} & & = & 1.45 \text{ ft.}
\end{array}
$$

The maximum value of H will occur when the rolling load covers the whole bridge. If the amounts of H for the points which have not yet been loaded are computed, the horizontal thrust for a complete travelling load will be found to be 26,206 pounds. The equilibrium curve for such a load will be a parabola; the ordinates y_1 and y_2 will be 1.19 feet, and the curve will pass the crown at a distance of + 0.5 feet vertically. As this parabola, when drawn if desired, will be found to lie at most points on the opposite side of the centre line from the curve for steady load, the effect of a complete rolling load will be to bring the arch quite near to actual equilibrium. The deviation at the crown will be reduced to — 0.2 feet, and, as the total thrust will then be 128,513 pounds, the greatest intensity of compression at that section, for a four-foot voussoir, will be $\frac{4 + 1.2}{4} \cdot \frac{128{,}513}{4 \times 144} = 290$ lbs. on the square inch. We have now examined in detail all of the critical points of this arch.

150. **Final Dimensions of Arch.** — The arch-ring was assumed, at the start, to be five feet deep. It is apparent, from our investigation and the conditions imposed, that this depth is greater than is necessary for the larger part of the arch, but is less than is required near the springings. For a travelling load of somewhat less intensity, a ring having a uniform depth of

five feet will be entirely satisfactory. Guided by these results, we may redistribute the steady load in the spandrels so as to bring the equilibrium curve for that load nearer the centre line at the springings. Another trial will probably accomplish the desired end, and the above curves for rolling load can be used anew. Otherwise, the arch-ring may be made four feet deep at the crown, and six feet and a half deep at the apparent springings, as shown on the right half of Fig. 45, and in that case the curves which have been discussed will lie within the middle third of the rib. Although the formulæ for the circular arch were derived upon the assumption that the rib was of constant thickness, the deviation which we suggest will hardly be of serious consequence. The tenacity of the cement, and the greater or less resisting power of the material immediately in contact with the ring, will sufficiently provide for all contingencies. We have therefore drawn this form as the final determined shape of the arch-ring, the centre line being undisturbed, and the radii of the intrados and extrados being about 95 feet and 104 feet respectively. One must remember, that, as the ring has been altered from a uniform depth of five feet, care must be taken to put a little more filling at the crown, and less at the springing, in order that the distribution of the steady load may be unchanged.

151. **General Remarks.**—If the exterior spandrel wall is massive, a separate equilibrium curve may be required for that portion of the ring which carries the wall: such portion will be subjected to a steady load equal to the weight of the wall, but need not be considered as carrying any travelling load. It was not our purpose to enter into the subject of the construction of stone arches, but to show the method of finding the forces which act on a given or assumed rib. Two or three matters, however, will be briefly referred to. If, at any point, the direction of the resultant pressure makes a considerable angle with the tangent to the centre line of the ring, the two voussoirs having a joint at that place might slip on one another if the joint were radial. No joint should deviate very far from a

plane perpendicular to the pressure. Generally this angle of deviation is too small to be of practical importance, and the joints are made radial or normal to the intrados.

In case several arches are built in a series, it is well to so proportion the span and rise of each, that the horizontal thrusts from steady load may nearly balance one another, as we shall then avoid a disturbance of one arch by the other, and can carry the arches on reasonably slender piers. If one arch has more thrust than the other, and the pier between the two yields, we have a change of span, like that due to temperature, so far as its treatment goes; and its effect upon the arches can therefore be determined.

As we know the direction, amount, and point of application of the thrust at the springing, we can easily construct the line of thrust, or equilibrium curve for the abutment, by combining the weight of the abutment and of the mass of masonry immediately above it with this thrust at the springing, the weight of the masonry just above this point being first compounded, and then the weights of successive portions of the abutment. Hence the required thickness of the abutment is ascertained.

152. **Exaggeration of Vertical Scale.**— Since some of the equilibrium curves may run quite close to the centre line, especially the one for steady load, it may improve the accuracy of measurement of the ordinates or displacements to exaggerate the vertical scale of the drawing. In this case, since all vertical lines will be increased in length, the load lines of the stress diagrams must be laid off with the same proportion to those which represent H. This suggestion immediately opens the question of the possibility of treating elliptic ribs.

153. **Elliptic Arch.**—If we refer to the original equations of condition for any rib, viz., $\Sigma\, EF \,.\, DE = 0$, $\Sigma\, EF = 0$, and $\Sigma\, EF \,.\, DB = 0$, it is apparent, that, if all the ordinates DE and EF of a circular rib are multiplied or divided by any given quantity, the summations indicated above will still equal zero, and that the ordinates y_1, y_0, and y_2, thus determined, will apply to an elliptic rib whose semi-axes are obtained from the radius

of a circular rib by the same multiplication or division. This fact is easily seen by reference to Fig. 43. Here are drawn a semicircular rib and two elliptic ribs, of the same span, but differing in height; one having one-half the rise, and the other one and one-fourth the rise, of the semicircle. We will suggest, that, to find points on an ellipse, a simple way is to draw from the same centre two semicircles whose radii are the semi-axes of the ellipse; then prolong any radius; from the point where it cuts one circle draw a horizontal line, and, from the point where it cuts the second circle, draw a vertical line; the intersection of the lines last drawn will be one of the desired points. This construction is seen in the figure, and, as one of the circles is needed subsequently, the method is convenient.

154. **Example.** — Taking a load at 30° from the crown of the semicircular rib as an example, we find, by turning to the table of § 99, that $y_1 = .360\ r$, $y_0 = 1.298\ r$, and $y_2 = .011\ r$: the polygon is plotted on the semicircle of the figure. In the upper sketch every ordinate for the ellipse being one-half of the corresponding ordinate for the circle from which it is projected, we have simply to substitute the semi-axis $a = \frac{1}{2}\ r$ for r, and we have $y_1 = .360\ a$, $y_0 = 1.298\ a$, &c. The equilibrium polygon may then be drawn, and it is apparent to the eye that it satisfies the imposed conditions alluded to in the last section. Similarly, for the other ellipse, we write a for r, in that way multiplying the ordinates of the semicircle by 1.25.

It is evident that the points of contraflexure are unchanged in horizontal position, as is also the *horizontal* distance of the imposed load from the crown; but the symbol $\alpha = 30°$ of the example has no significance in the ellipse as denoting the *angular* distance of the load from the crown. We must, in place of such notation, either draw the semicircle which has the *span* for a diameter, and work from that, as has here been done, or else for α read $r \sin \alpha$, where r equals horizontal semi-axis of the ellipse, and lay off the distance from the centre on the diameter to locate the foot of y_0. A segment of a semi-ellipse can be treated exactly as a segmental circular rib is treated: it will be

necessary to draw the semicircle whose radius is the horizontal semi-diameter of the ellipse, and then to determine, by projecting the springing of the elliptic rib vertically upon the semicircle, what is the value of β to be introduced in the equations for y_1, &c.

We see, also, from either the stress diagram, or a consideration of the equation for H, that in proportion as the ordinates are diminished so is H increased: thus, for the flat ellipse of our figure, H is double the value of H for the semicircle; and, for the ellipse of large rise, H is $\frac{4}{5}$ that of the semicircle. All of these remarks apply equally well to the rib hinged at the ends; and therefore the elliptic rib may be readily introduced in bridges or roofs, where it is desirable to have either a low arch rising rapidly from the springings, or a very high one.

155. **Treatment for Horizontal Forces.** — Horizontal forces can be treated equally well by considering the elliptic roof as a projection of a circular arc. In this case it will be necessary, since x_1, x_0, and x_2, are measured horizontally, to use the projecting circle which has the same rise, but different span; when the abscissæ will be changed with the span, and the point of application of the horizontal force will continue on the same horizontal line.

156. **Catenary.** — There is one special case which it may be well to take up. It not seldom occurs in construction that an opening in a wall is to be spanned by an arch, and the masonry at top is limited by a horizontal line, while the load is permanent. If we can make the arch of the form of the equilibrium curve for such a load, we may get a rib of good stability with a very moderate depth. A method of constructing such a curve will now be shown. We stated, in the early part of the book, that the curve assumed by a cord or chain hanging between two points of suspension, and under the action of its own weight only, was called a *catenary*. The load is distributed uniformly along the curve; that is, the intensity per foot of the curve is constant. To draw a catenary, proceed as follows: Lay off on a vertical line, 1–11, Fig. 41, a convenient number

of equal spaces, 1–2, 2–3, &c., the more the better, and let each of these spaces represent the weight of a certain short length of chain, as, for instance, in our figure, 6.4 feet. They may be of the same length as the pieces of chain, if desired. As we do not know the value of H at present, assume it, and draw 1–0 horizontally, equal to H; draw 11–0; consider the weight of the first piece of chain to be concentrated at its middle, and make A B equal to one-half piece of chain, say 3.2 feet; then draw B C parallel to 10–0, C D parallel to 9–0, and so on, B C, C D, &c., being successively laid off equal to one piece of chain, here 6.4 feet. We shall close with N O parallel to 1–0, and equal in length to A B. A curve from A to O, tangent to this broken line, will be a catenary. If 1–11 represents the weight of the chain A O, 1–0 will represent the tension at O, and hence the weight of a piece of chain, which, hanging over a smooth peg at O, will keep the curve in equilibrium. Let O P represent the length of the piece which weighs H, or 0–1. Then a horizontal line P Q, drawn through P, is known as the directrix of the catenary. This curve has some peculiar attributes, which may be deduced by mathematical analysis, and may be verified, in any particular case, from the drawing. Any vertical ordinate to the curve will represent the tension along the curve at the point to which it is drawn. Further, this curve will also be in equilibrium under a load which shall fill the entire area included between P Q and O A with a uniform load per square foot of the area. Since, however, when O P is given, the entire curve is fixed, it is possible to make a catenary curve of but one span and rise, if the depth of load at the crown is fixed; and hence the catenary itself is not applicable to the form of an arch where the three quantities just mentioned are given. This arises from the fact that all catenaries are similar figures: therefore, two of the above quantities being given, as for instance, span and rise, the third, the depth at crown, is definitely determined from them.

157. **Transformed Catenary; Example.**—It is possible, however, to find a curve which shall be in equilibrium under

such a load, when the span, rise, and depth are all given. In the same way that an ellipse is derived by projection from a circle, a curve, called a transformed catenary, can be projected from a catenary, and will be in perfect equilibrium under the desired or prescribed wall. While some of the quantities used are derived by mathematical analysis, which we will not insert here, the accuracy of these quantities can be verified from the diagram.

Let it be desired to find the form of the arch, of half span P Q, which shall be in equilibrium under masonry whose depth at the crown shall be S P, and at the springing R Q. It is understood that the arch will be inverted from this figure, and it will be seen that this type of arch may be applied to any span and rise. Let P Q $= c$, P S $= h_0$, Q R $= h_1$, P O $= m$, and Q A $= y_1$. The first step will be to find the value of P O, and thus determine the original catenary. This will be done by solving the equation

$$m = \frac{c}{2.30158 \times \log\left(\frac{h_1}{h_0} + \sqrt{\frac{h_1^2}{h_0^2} - 1}\right)};$$

where *log.* denotes the common logarithm of the quantity in the parenthesis. Let the half-span be 30 feet, the rise 8 feet, and the depth of load at the crown 2 feet; then is h_1 10 feet, and the above expression becomes

$$m = \frac{30}{2.30158 \times \log(5 + \sqrt{24})} = \frac{30}{2.29242} = 13.09 \text{ ft.}$$

Then by proportion

$$h_0 : m = h_1 : y_1, \quad \text{or} \quad y_1 = \frac{m\,h_1}{h_0} = 13.09 \times 5 = 65.45 \text{ ft.}$$

We next obtain from the following formula, the length of the catenary,

$$s = \sqrt{(y_1^2 - m^2)} = \sqrt{(65.45^2 - 13.09^2)} = 64.1 \text{ ft.},$$

and

$$\frac{P_1}{H} = \frac{s}{m} = \frac{64.1}{13.09} = 4.9.$$

We may now proceed to draw the catenary between the points A and O. Any length of load line may be laid off, and H then drawn of the proper proportionate amount just found. But, if preferred, P_1 may be made equal to the weight on the catenary, which will be the area between the curve and the directrix multiplied by the weight of a cubic foot of masonry. The area can be proved equal to $m\ s$, or the product of P O by the length of the curve just found. Divide the load line into a certain number of equal parts, and divide s by the same number. Then proceed with the construction of § 156.

158. **Construction.** — The transformed catenary must be a projection of the catenary so drawn, and the load and load line will be reduced in the same proportion. To save the trouble of redividing the load line, multiply 1–0 by the ratio $m \div h_0$; that is, enlarge the scale of the stress diagram, and lay off that distance from 1 to 0′. Radiating lines from 0′ to the old points of division will be parallel to those which might be drawn from 0 to new points of division; therefore, starting from R, draw the curve R S by making its sides parallel to lines radiating from 0′, and bringing the points B′, C′, D′, &c., vertically below B, C, D, &c. But it must be remembered that H in the new curve is the same in amount as H in the old one, while P_1, the vertical component of the reaction, is reduced in the ratio just referred to. The rib need only be deep enough to have strength to resist the thrust. Fig. 42 shows the arch in an erect position.

159. **Many-centred Arch.** — If it is wished to lay out an approximation to the transformed catenary, composed of arcs of circles, draw normals at the middle points of the successive sides of our construction, and, to get them accurately, make them perpendicular to the radiating lines of the stress diagram. Prolong them until they intersect one another, and, on or near the curve which can be sketched through those intersections, select as many centres as may be desired for the circular arcs. Thus arches of three, five, or seven centres may be drawn, which will be good approximations to the transformed catenary.

CHAPTER X.

STIFFENED SUSPENSION-BRIDGES.

160. **Necessity for Stiffening.** — That the curve of equilibrium for the cable of a suspension-bridge, when the load is supposed uniform per horizontal foot, and covers the entire span, is a parabola, was proved in § 28, Fig. 6. The steady load will always be carried by the cable. When, however, a moving load is upon the structure, the cable will tend to become flatter in curvature over the lightly-loaded portion, and more curved over the heavily-loaded portion, thus throwing the roadway from its proper line. Some means of stiffening the roadway or chain against distortion is therefore needed. Bridges subjected to travelling loads of but moderate amount may be stiffened by the longitudinal beams of the roadway; but heavy loads necessitate the employment of trusses or girders in some form.

161. **Inverted Arch.** — If the cable is divided into two parallel members, braced together as shown in Fig. 46, it becomes an inverted arch, and follows the treatment already given in either Chap. II., III., or IV., depending upon whether hinges are or are not introduced at the piers and the middle. From the fact that the cables are carried over the towers to anchorages, and that movement over the top of the tower will take place both from change of load and change of temperature, the span cannot be assumed invariable: hence there is greater liability to alteration of stress in the several members from unavoidable causes; and a larger factor of safety than is commonly employed

in structures will be appropriate. The introduction of three hinges will do away with these sources of error. This type of stiffening truss will be discussed further in connection with the one which follows.

162. **Horizontal Girder.** — It is much more common to employ a horizontal truss or girder, as shown in Fig. 47, to stiffen the suspension-bridge. If we note that the office of the arch or inverted arch is twofold, — first to resist the direct stress, and, second, to resist the bending moments at successive sections, — we see that the horizontal girder of this figure will be subject to the same bending moments at similar sections as the inverted arch or braced rib of Fig. 46, while the chain will here carry the direct stress, which in the former case was also resisted by the rib.

If the truss is hinged at the middle as well as at the abutments, it comes under the class of Chap. II.; and the effect of one or more loads is easily determined. We may draw Fig. 48, if desired, and find by inspection the extent of rolling load required to produce the maximum bending moment of either kind at any point. See § 32. Thus, at one-fourth the span from one abutment, the maximum bending moment of one kind occurs when the rolling load covers four-tenths of the span on the same side; and the maximum bending moment of the opposite kind, when the rolling load covers the other six-tenths of the span. The maximum moment at a point near the abutment is found when the head of the load is at one-third the span from that abutment. These values are easily deduced by finding the horizontal distance of the point of intersection D, in Fig. 48, on A F, of that line, which, starting from B, passes through E, the extremity of a certain ordinate. Those authors who make maximum bending moments at all points occur, for a stiffening girder hinged at ends and middle, when the half-span is covered, are in error. The shear diagrams are constructed as explained in the earlier chapters. The construction for normal shear will be applicable to Fig. 46, and the vertical shear diagram to the stiffening truss of Fig. 47.

163. **Distribution of Rolling Load between Cable and Truss.** — It may be well to call more particular attention to the distribution of the rolling load between the truss and cable of Fig. 47, and the way in which bending moments are caused in the unloaded portion of the horizontal girder. If the bridge is unequally loaded, and no stiffening appliances are used, a distortion is produced, as explained in the first section of this chapter. When a weight W is applied on a suspension-bridge of half-span c, at any point distant b from the middle hinge, we know, in the first place, that the *total* reaction at A, Fig. 47, the end farthest from the weight, is $W\frac{c-b}{2c}$, and at B is $W\frac{c+b}{2c}$; and, in the second place, as there can be no shear in the cable, we see, from the equilibrium polygon of Fig. 48, and the lines 0–4 and 0–3, drawn in the stress diagram parallel to the tangents to the cable at the tops of the towers, that $5\text{–}4 : H = 2k : c$, or $5\text{–}4 = \frac{2k}{c}H$. By § 23, $H = \frac{c-b}{2k}W$; therefore the amount of vertical force combined with H of the cable is $W\frac{c-b}{c}$. Hence at A and at B the cable itself produces a reaction of $W\frac{c-b}{c}$, the balance of the reaction comes from the truss; the reaction of the truss at A will therefore be $-W\frac{c-b}{2c}$, and at B will be $W\left(\frac{c+b}{2c} - \frac{c-b}{c}\right) = W\frac{3b-c}{2c}$. This reaction also will be negative when b is less than $\frac{1}{3}c$. Such is the case in Fig. 48, for the polygon A D B; and we have a corroboration in the negative bending moments near each end.

As the vertical force at A or B from the cable is the load on the half-span of the cable, and this load must be uniformly distributed horizontally to keep the cable in its curve, the intensity of vertical pull exerted between the cable and the rods per horizontal foot is found by dividing the above force by the half-span: hence it is $W\frac{c-b}{c^2}$. This will be the *upward* pull on

the girder per horizontal foot at all points and the cause of the bending moments. Of course at the point of application of W the resultant force acts downward. The action of a continuous load over a greater or less portion of the girder will follow the same law; and we shall have downward forces on the loaded portion of the girder equal to the difference between the imposed load and the pull of the vertical rods, and upward forces on the unloaded portion.

It is convenient to notice that the amount of W carried by either half of the cable is that portion which would be carried by the middle hinge if the half-girder alone supported W. As the girder reaction at the farther abutment is one-half of this amount, and the half-girder on the unloaded side is subjected to a uniform upward force, the shear on the middle hinge will also be one-half of this amount, or $W\frac{c-b}{2c}$. The shear diagram is given in Fig. 48. For any extent of load it will now be easy to find the amount carried by the cable; for we have only to calculate the portion which would come upon the middle hinge, were that a point of support of a simple truss of span c, and this portion will be the load on the half-cable.

164. **Comparison of Inverted Arch and Horizontal Girder.** — All statements in regard to the horizontal stiffening girder are equally true of the two parallel chains with bracing. While, in the bridge formed of cable and horizontal girder, the girder resists bending moments, and the chain takes up the direct stress, in the latter case the cables have to resist both moment and direct stress. But the maximum direct stress at any section, half of which is borne by each cable, occurs when the bridge is fully loaded: the maximum bending moment is found with a partial load, at which time the direct stress is less. Hence less material is theoretically required for the cables and truss of the type of Fig. 46 than for one like Fig. 47, — perhaps three-fourths as much. The introduction of the middle hinge in the axis of the rib of Fig. 46, with connections of sufficient strength to transmit the cable stresses, is attended with a little difficulty, which does not exist in the other case.

The three-hinged girder or rib may have the third hinge removed from the middle towards one end, as shown in Fig. 50, where one portion of the girder takes the form of a short link, extending to the first suspending rod. The same device may be introduced in an arch. The effect on the equilibrium polygon and the derived quantities may at once be seen.

165. **Horizontal Stiffening Girder hinged at Ends only.** — In case the middle hinge is omitted, the girder will be exposed to bending moments, as explained in Chap. III. Here, again, an inspection of Fig. 8 will show the extent of load required to produce maximum M of either kind; and an examination of the table of bending moments in the chapter referred to will show that an absolute maximum M occurs at one-fourth of the span from either abutment for a continuous load extending from one end to a point distant 0.43 of the span from the end nearer to the point of maximum M. Its amount is about $\frac{1}{7.5}$, or .133 of the maximum moment at the middle of an unassisted girder of the entire span. The stretching of the cables on both sides of the towers impairs the accuracy of these deductions. With a truss hinged at the middle, the sagging of the main cable, as well as the change of temperature, is of little consequence. From the value of Y_1, § 50, it is evident that $\frac{5}{32}(1 - n^2)(5 - n^2)$ W is carried by either half-chain, and this quantity divided by c will give the intensity of upward pull on the truss from a load W at one point. The above amount is again that which would be carried to the point of contraflexure of the truss, if that were the point of support of the unassisted truss, and the truss were discontinuous over the support. (Compare Rankine's "Applied Mechanics," p. 375, *note.*)

If the ends of the girder are fixed in direction, we have the case of Chap. IV. Enough has been said to plainly indicate the treatment.

166. **Stiffening Girder of Varying Depth.** — Returning anew to the case of the stiffening girder with three hinges, it is

evident, that if the girder has a variable depth, greatest at the points of maximum bending moment, the stresses in the flanges or chords will be diminished proportionally, with an economy of material. If, at the same time, the girder is itself the suspension cable, we can so adjust the depth, that the flange stresses for a partial load shall never exceed those arising from an entire load. Modifications having this end more or less in view have been suggested and carried out. Let us first draw, in Fig. 49, the equilibrium curve for a rolling load alone over half the span. While this curve will not give maximum bending moments, it will not differ greatly from the curves of maximum M, and it offers a very convenient and sufficiently accurate basis of comparison. Its form will be a straight line over the unloaded half of the span, and a parabola tangent to that line for the remaining portion. As the tangent at the abutment end of this parabola meets the tangent from the other end in the vertical through the centre of gravity of the load, the tangent A D is at once drawn. Draw the chord A C. The parabola cuts the middle vertical ordinate E D from the chord A C at its middle point F. If the height of the original parabola of the cable is k, the ordinate at one-fourth the span is $\frac{3}{4}k$. G D $= \frac{3}{2}k$; G E $= \frac{1}{2}k$; therefore E D $= k$; E F $= \frac{1}{2}k$; and F G $= k$. Hence the remaining ordinate for bending moment at one-fourth the span is $\frac{1}{4}k$ on either side, and of opposite signs.

167. **Ead's Arch, or Lenticular Stiffening Girder.**—If the two half-ribs of the arch of Fig. 51, or of the stiffened suspension-bridge, are each made of two equal parabolas, the outer ones being the continuous equilibrium curve for a complete load, the vertical depth of the semi-girders at their middle sections E and F will be one-half the rise or height, k. Let us denote the horizontal thrust or tension from steady load w by H; that from a full rolling load w', by H′. The horizontal stress due to a rolling load extending from one abutment over half the span will be $\frac{1}{2}$ H′; for a similar load over the other half-span must give an equal stress, and both combined must equal H′. When the above bridge is fully covered with mov-

ing load. the equilibrium curve will coincide with the continuous curve, and the stress at each section of the main cable will be that due to $H + H'$. The auxiliary ribs and bracing will experience no stress. When the bridge is half loaded, say from C to B, the equilibrium polygon for rolling load will be the one sketched in our figure; it passes at I, $\frac{1}{4}k$ below the main cable at D, and through the middle or axis of the truss A C. The horizontal component of the stress at D, due to $\frac{1}{2}H'$ at I, is, from the equation of moments about E, $\frac{3}{4}H'$; that is, $\frac{1}{2}H' \cdot \frac{3}{4}k =$ hor. comp. at D $\times \frac{1}{2}k$. Taking moments about D, $\frac{1}{2}H' \cdot \frac{1}{4}k = -$hor. comp. at E $\times \frac{1}{2}k$; or horizontal component at E is $-\frac{1}{4}H'$. At F and G the horizontal component is, in each member, $\frac{1}{4}H'$. The minus-sign denotes opposite stress, here compression; in the arch, tension. We may therefore write the following table of cases:

Horizontal component of stress at .	E	D	F	G.
With steady load only	0	H	0	H,
" " and one-half rolling load	$-\frac{1}{4}H'$	$H+\frac{3}{4}H'$	$+\frac{1}{4}H'$	$H+\frac{1}{4}H'$,
" " " complete " "	0	$H+H'$	0	$H+H'$.

Since F and G change places with E and D for a load on the other half-span, we see that the lower member, or main cable, experiences a horizontal component which fluctuates from H to $H + H'$, always tension; while the auxiliary rib has a stress whose horizontal component ranges between $\frac{1}{4}H'$, tension, and $\frac{1}{4}H'$, compression. The bracing will undergo no stress from a full load. The stress in the bracing for partial loads may be worked out by the method of the previous chapters for finding the amount of shear remaining after subtracting the vertical components for the two cables at a section, by the method of Part II., "Bridges," Chap. V., or by drawing stress diagrams as given in Part I., "Roofs."

As the parabola through I is a *projection* of that through D, the above deductions for the points D and E are true for the other points of the girder. Although, as pointed out in § 162,

the bending moments are a little greater for loads which cover not quite half the span, it is evident that the horizontal component of the stress in the main cable can never exceed $H + H'$, and in the counter-rib will but slightly exceed $\pm \frac{1}{4} H'$. This form of arch was designed and patented by James B. Eads: a paper upon it by him may be found in the "Transactions of the American Society of Civil Engineers," vol. iii., No. 6, October, 1874.

168. **Bowstring Stiffening Girder.** — If the auxiliary members connecting the hinges A, C, and B, Fig. 52, are straight, we have a variation in the method of stiffening and a change in the stresses. The equilibrium curve A F C I B, for a rolling load over one-half the span, is also drawn here, coinciding with A C, and passing through I, $\frac{1}{4} k$ below D. The steady load will be entirely carried by the main cable as before, as will also a complete rolling load. The half rolling load, being entirely supported on the left by A F C, will cause in that member a tension whose horizontal component is $\frac{1}{2} H'$; a horizontal tension in D, of H', and a horizontal compression in E, of $\frac{1}{2} H'$, as is found by similar equations of moments to those in the last section. There results, then, for this type the following cases: —

Horizontal component of stress at . .	E	D	F	G,
With steady load only	0	H	0	H,
" " " and one-half rolling load	$-\frac{1}{2} H'$	$H+H'$	$+\frac{1}{2} H'$	H,
" " " " complete " "	0	$H+H'$	0	$H+H'$.

The stress on the main cables will be very slightly increased for some partial loads, as shown before. The increase will, however, be small, for the direct stress is decreased at the time the bending moment is increased; so that the absolute maximum may be called $H + H'$ without any error of importance. The stress in the straight stiffening rib ranges from a tension of $\frac{1}{2} H'$ to a compression of $\frac{1}{2} H'$. While the member A C or C B has to resist double the force of the preceding case, and that

force also completely reversed for a moving load over one-half of the bridge, the unbraced lengths are shorter than in Fig. 51, the construction of a straight member is simpler, and the web members are only one-half as long: the cost may therefore be sufficiently influenced to cause this design to commend itself more to the practical builder than does the former. A notable example of this type is the Point Bridge at Pittsburgh, Penn., eight hundred feet span, built by the American Bridge Company of Chicago, in 1876.

169. **Fidler's Stiffened Suspension-Bridge.** — Again, let us conceive of two cables, A F C D B and B E C G A, Fig. 53, each separately subject to, and in equilibrium under, a rolling load over one-half the span, and then let their places be taken by the two girders shown. A C and C B will be straight, as in the last figure; A G C and C D B will be parabolas, each tangent at C to the chord of the other; and the equilibrium curve for a complete load will pass through the middle of each truss, as shown by the dotted line. These trusses are, therefore, of the form of Fig. 52; but they have a depth equal to that of the trusses of Fig. 51. The horizontal component H, of steady load, and H′, of complete rolling load, will be carried equally by both members of each truss, $\frac{1}{2}$ H and $\frac{1}{2}$ H′ on each. A rolling load on the right half of the span will cause a horizontal tension of $\frac{1}{2}$ H′ at D and at F. We may, then, write, for this type,

Horizontal component of stress at	E	D	F	G.
With steady load only	$\frac{1}{2}$H	$\frac{1}{2}$H	$\frac{1}{2}$H	$\frac{1}{2}$H,
" " " and one-half rolling load	$\frac{1}{2}$H	$\frac{1}{2}$H+$\frac{1}{2}$H′	$\frac{1}{2}$H+$\frac{1}{2}$H′	$\frac{1}{2}$H,
with steady load and complete rolling load	$\frac{1}{2}$H+$\frac{1}{2}$H′	"	"	$\frac{1}{2}$H+$\frac{1}{2}$H′.

The stresses will, therefore, always be tension, and the horizontal component will vary in each member from $\frac{1}{2}$ H to $\frac{1}{2}$ (H + H′), a most favorable showing for the structure. The

remark of § 162 in regard to maximum bending moments applies here also. The maximum stresses in the bracing can be worked up in the way thought most convenient. This type may also be analyzed as two inverted bowstring girders, a weight on one causing simply a tension in the tie of the other and an inclined reaction in its line at the middle hinge. Hence the investigation of the bowstring girder in Part II. may be applied here. A very interesting analytical discussion of the types of bridges and arches of this chapter may be found in "Engineering," vol. xx. for 1875, from the pen of Mr. T. Claxton Fidler, the inventor and patentee of the type discussed in this section.

170. **Ordish's Suspension-Bridge.**—Another stiffened suspension-bridge, in which the problem of resisting distortion from a partial load is solved in quite a different way, is what is known as Ordish's, shown in Fig. 55. The Albert Bridge over the Thames, at Chelsea, Eng., is of this type; and one of moderate span has been erected over the Pennsylvania Railroad, at 40th Street, Philadelphia. Here a certain initial stiffness is given to the platform itself, and it is then directly supported at several points from the tops of the towers. It is intended that the weight shall be entirely carried by the inclined ties. As these ties, from their length, would sag considerably under their own weight, a passing load would cause the roadway to move vertically; for an increased pull on a tie would tend to straighten it. They are, therefore, suspended, at the joints in the several bars which make up the ties, from a light cable, which is designed simply to carry the weight of the ties; and the suspending rods are so adjusted, that the ties shall be straight. No movement of the roadway of any importance can then take place. The analysis is very simple.

171. **Erect and Inverted Arch combined.**—The bridge over the Elbe, at Hamburg, one span of which is shown in Fig. 54, is a combination of the erect and inverted arch. This construction dispenses with abutments to withstand a thrust, as the thrust of the upper rib will at all times be balanced by the

tension of the lower rib. If the ribs are of equal stiffness, any load may be considered as divided equally between the two systems: if the ribs, while having the same curvature, are not alike in cross-section, the load will probably be distributed in the ratio of their moments of inertia. As the erect arch always tends to move away from its equilibrium curve, and the inverted arch to approach the equilibrium curve, the tangents at the abutment ends will move in the same direction, and therefore the structure should be treated as hinged at the ends, unless each flange is firmly bolted to the skew-back. If the structure is carried on columns or a pier, it appears to us that the ends cannot be rigid, and we judge that the two ribs will begin to turn about the middle of the depth without the introduction of a pivot or hinge.

The effect of temperature is annulled. Also the shortening of the erect arch under the direct compression being opposite to the extension of the inverted arch under the direct tension, the span will tend to remain unaltered; but the ribs themselves will be changed in form, one rib flattening as the other becomes more convex. If, in making such a design, the section of the arch is found to differ much from the section of the inverted rib, it will be well to calculate the relative deflections of the two ribs at the middle. The amount of load each will carry varies inversely as the deflection under equal loads, since they must deflect equally; and hence, if the arch is first designed of such shape, for the purpose of resisting compression, that it is stiffer or has less deflection than the chain, when each has one-half the load, the cross-section of the arch must be increased, and that of the chain may be diminished. This type of structure must not be confounded with a lenticular girder: the absence of bracing between the ribs makes them independent.

CHAPTER XI.

BENDING MOMENTS FROM CHANGE OF FORM.[1]

172. Displacement from Bending Moments. — It follows, from the fact that the arched rib moves away from the equilibrium polygon or curve, that the bending moments and chord stresses will have a slight tendency to increase. When the rib changes in shape, however, the equilibrium polygon must also move enough to still satisfy for the new form the equations of condition by which it was first established, and this movement will in some measure counteract the former. Besides, the equilibrium curve for steady load generally runs so close to the axis of the rib, that the change of shape from bending moments is very slight; and, even when the influence of rolling load is added, the increments of the bending moment ordinates are too small to be of material consequence.

The vertical displacement at any point E, Fig. 56, produced by any load, will be found, for the parabolic rib, by taking *area moments*, as explained in Part II., "Bridges," Chap. VI., or for the circular rib by summing the ordinates as usual along the rib. As was done in the treatment of beams, it will here be necessary to find the point D where the tangent to the rib in its new form is horizontal, which point will not be at the crown,

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[1] Many of the deductions in this chapter are only intended as guides in practical construction, to indicate where, and to show approximately how much, additional stress may be anticipated from change of form. Exact results are not attempted.

except for symmetrical loads. D is then to be assumed momentarily as a fixed point, and the deflection or area moment of A and E obtained with reference to it: the subtraction of the latter from the former gives the displacement of E relatively to the abutment A; that is, from the area moment between D and A subtract the area moment between D and E; and the remainder, when multiplied by H $\div$ **E I**, will be the vertical displacement of E. As just stated, these displacements may be neglected.

173. **Displacement and Bending Moments from Compression.**—The thrust which exists at each section of the rib must, by its compression of the particles, cause a shortening of the rib, and, as the shorter rib must fit the same abutments, it is necessarily lowered at the crown. The resulting bending moments may be of consequence. So far as the rib retains sensibly its old form, parabolic or the segment of a circle, the equilibrium polygon is lowered proportionally to the sinking of the rib, as indicated in Fig. 57, in order to still satisfy the equations of condition; but, as the deflection v at the crown is very small compared with k, the alteration of the bending moment ordinates is very trifling. On the other hand, this lowering of the apex of the equilibrium polygon at once increases the value of H, offsetting the change first pointed out. This will be seen, also, from the values of M, § 44, into which k does not enter. The bending moments from the external load are therefore practically unaltered by the change of form.

To produce this change of form, however, or to bring the arch down to its new position, requires a change of inclination, and consequently a bending moment, at most points of the rib. The strains thus induced should be examined. Strictly accurate theoretical investigations for the different ribs cannot easily be made; but formulæ may be deduced which will serve all practical purposes.

174. **Parabolic Rib hinged at Ends.**—The parabolic rib which we have treated varies in cross-section, from the crown

to the springing, according to the secant of the inclination to the horizon, § 37; and, as the magnitude of the direct thrust for a complete uniform load varies in the same way, the intensity of direct compression per unit of cross-section arising from H will be constant, and every unit of length of arc will be shortened by that thrust the same amount, so that the arch will be altered as if exposed to a change of temperature. We will assume that the new form of the rib is still a parabola with a rise k' in place of k, but with the original span $2\,c$.

By definition, Part II., "Bridges," § 85, the modulus of elasticity $\mathbf{E}$ equals the intensity of stress divided by the shortening of a unit's length. Let the constant intensity of thrust equal the thrust at the crown H, divided by the cross-section at the crown A; let the compression of a unit's length equal the difference, $s-s'$, between the lengths of arc before and after compression divided by the original length s. Then

$$s - s' = \frac{\mathrm{H}\,s}{\mathrm{A\,E}}.$$

An approximate formula for the length of a parabolic arc is, in our usual notation, $s = 2\,c + \frac{4}{3}\frac{k^2}{c}$. The value of s' will be obtained by writing k' for k; then

$$s - s' = \frac{4}{3\,c}\,(k^2 - k'^2) = \frac{\mathrm{H}\,s}{\mathrm{A\,E}} = \frac{2\,\mathrm{H}}{3\,\mathrm{A\,E}} \cdot \frac{3\,c^2 + 2\,k^2}{c}.$$

As v, the deflection at the crown and the difference between k and k', is very small, we may write, without sensible error, $k - k' = v$, and $k + k' = 2\,k$; whence $k^2 - k'^2 = 2\,k\,v$, and we have

$$\frac{8}{3\,c}\,k\,v = \frac{2\,\mathrm{H}}{3\,\mathrm{A\,E}} \cdot \frac{3\,c^2 + 2\,k^2}{c}, \quad \text{or} \quad v = \frac{\mathrm{H}}{4\,\mathrm{A\,E}} \cdot \frac{3\,c^2 + 2\,k^2}{k}.$$

It was proved, in § 36, that this rib deflected vertically like a horizontal beam of uniform section: hence to bring the arch down to its new position will create bending moments at all points such as would accompany the same deflection in a

straight beam, supported at the ends, uniformly loaded, and of a cross-section equal to that of the rib at the crown. In Part II., "Bridges," § 95, we found, for a beam supported and loaded as above with w per foot,

$$v = \frac{5}{384} \cdot \frac{w l^4}{\mathbf{E I}} = \frac{5 w c^4}{24 \mathbf{E I}} = \frac{5 \mathrm{M}_0 c^2}{12 \mathbf{E I}},$$

if M_0 is the bending moment at the middle. Equating these two values of v, we obtain

$$\frac{5 \mathrm{M}_0 c^2}{12 \mathbf{E I}} = \frac{\mathrm{H}}{4 \mathrm{A} \mathbf{E}} \cdot \frac{3 c^2 + 2 k^2}{k},$$

or

$$\mathrm{M}_0 = \frac{3 \mathbf{I} \mathrm{H} (3 c^2 + 2 k^2)}{5 \mathrm{A} c^2 k},$$

the additional positive bending moment at the crown of the arch, caused by its compression under the thrust H.

The bending moments at other points may then be taken to compare with those of the beam, that is, as the ordinates to the parabola, being $\frac{3}{4} \mathrm{M}_0$ at the quarter-span.

175. **Remarks**; **Example.**—It will be noticed that $\mathbf{E}$ has disappeared from the expression for M_0: hence the bending moment will be the same, whether the material be iron, steel, or wood. As $\mathbf{I}$ contains A, and may be written $n \mathrm{A} h^2$, Part II., "Bridges," § 86, n being a numerical factor, it is seen that the bending moment from deflection of the rib due to compression increases with the square of the depth of the rib, and, as $\mathrm{M} \div h$ equals the flange stress, this stress will increase directly as the depth. To diminish the effect of change of form alone, employ a shallow rib.

If $\mathrm{H} = 20$ tons, $c = 100$ feet or $l = 200$ feet, $k = 20$ feet, and $h = 2\frac{1}{2}$ feet, for a rib with two plate flanges and thin or open web, $\mathbf{I} = 2 \{\frac{1}{2} \mathrm{A} \, . \, (\frac{1}{2} h)^2\} = \frac{1}{4} \mathrm{A} h^2$, and

$$\mathrm{M}_0 = \frac{3 \times 25 \times 20 \times 30{,}800}{5 \times 16 \times 10{,}000 \times 20} = 2.9 \text{ ft. tons at crown,}$$

giving 1.16 tons compression on upper flange, and an equal tension on lower flange.

176. Displacement from Change of Temperature. — The deflection produced by a fall of temperature in the parabolic rib hinged at the ends will be found by taking the area moment of the half parabolic segment, Fig. 16, from the crown to the springing about one abutment, and multiplying by $\mathrm{H} \div \mathbf{E\,I}$. Hence, as in Part II., "Bridges," § 95,

$$v_t = \frac{\mathrm{H}_t}{\mathbf{E\,I}} \cdot \tfrac{2}{3} c\,k \cdot \tfrac{5}{8} c = \tfrac{5}{12} \cdot \frac{\mathrm{H}_t}{\mathbf{E\,I}} \cdot c^2\,k,$$

the deflection at the crown when the temperature falls, and the rise of the crown when the temperature rises. One may prefer to consider the rib in its new position as the proper curve from which to obtain the area moment. If it is assumed to still be a parabola with the rise k', we have

$$v = \tfrac{5}{12} \frac{\mathrm{H}}{\mathbf{E\,I}} c^2\,k', \text{ and } k' = k \pm v.$$

Substitute this value of k', and v becomes

$$v = \frac{5\,\mathrm{H}\,c^2\,k}{12\,\mathbf{E\,I} \mp 5\,\mathrm{H}\,c^2}.$$

This deflection is the result of the bending moments arising from H_t, and is not to be regarded in the light of the preceding section. The moments were computed in § 74. These moments will be slightly altered by the movement, as it shortens or lengthens the ordinates; but H_t will be changed in the opposite direction, reducing the actual modification of the moments. Since

$$\mathrm{H}_t = \frac{15}{8} \cdot \frac{t\,e\,\mathbf{E\,I}}{k^2}, \quad v_t = \frac{25}{32} \cdot \frac{t\,e\,c^2}{k},$$

a quantity independent of the cross-section of the rib, and, so far as the material is concerned, affected by the co-efficient of expansion only.

The bending moments due to the direct thrust, whether arising from a load or change of temperature, have been considered, as well as the resulting deflection. When the temperature rises, H_t is thrust, and in itself tends

to shorten the rib, and thus reduce the above amount of rise due to expansion. The ratio of the two deflections will be

$$\frac{v}{v_t} = \frac{\mathrm{H}_t}{4\,\mathrm{A\,E}} \cdot \frac{3\,c^2 + 2\,k^2}{k} \div \frac{5}{12}\,\frac{\mathrm{H}_t}{\mathrm{E\,I}}\,c^2 k = \tfrac{3}{5}\,n\,h^2\left(\frac{3}{k^2} + \frac{2}{c^2}\right).$$

In the example previously cited this ratio becomes

$$\frac{v}{v_t} = 0.6 \times \frac{25}{16}\left(\frac{3}{400} + \frac{2}{10,000}\right) = .0072,$$

a reduction of three-fourths of one per cent. When the temperature falls, H_t is a tension, and, in lengthening the rib, slightly reduces the deflection.

The deflection for a co-efficient of expansion of .000007 and a range of temperature of 30° will be, in our example of § 175,

$$v_t = \frac{25 \times 30 \times .000007 \times 10,000}{32 \times 20} = .082 \text{ ft.} = 1 \text{ inch.}$$

[The expansion or contraction of a straight bar may be conveniently stated as ¼ inch in one hundred feet for 30° F.] The theoretical movement of the rib at the crown for a range of 30° above and below the temperature at which it was constructed will therefore be two inches. The actual movement is generally less than theory would indicate, owing to gradual transition from one extreme to another, protection of some portions of the structure from extremes of temperature, as by shielding from the direct rays of the sun, &c., and, finally, imperfect freedom of motion.

177. **Initial Camber for Arch.**—It may be expedient to make the rib a little longer than the distance between the springings to compensate for the amount of compression which will arise from the steady load, or else to wedge up the springing points until the crown of the rib, when not under strain, shall be a distance v above its normal position: the rib will then, when in place and under its steady load, come down to the curve for which it is designed, and will be free from that portion of initial bending moment due to change of form from steady load. This will be true, because, in forcing the rib up,

we have introduced bending moments of the opposite kind to an equal amount. An additional allowance may be made for an ordinary travelling load. If the rib is to be made longer to offset the compression, find v, § 174, or H from steady load, and make the parabolic rib of a span $2c + u$ and a rise k, so that, when sprung into place on a span $2c$, it would rise to a height $k + v$, if it were not compressed at the same time.

Noticing, from § 174, that this compression acts like a fall of temperature in shortening the rib, we have, from § 74,

$$\mathrm{H}_t = \frac{15}{8} \cdot \frac{\mathbf{E}\,\mathrm{I}}{c\,k^2} \cdot t\,e\,c = \frac{15}{8} \cdot \frac{\mathbf{E}\,\mathrm{I}}{c\,k^2} \cdot \frac{u}{2},$$

since u must equal $2\,t\,e\,c$. But $\mathrm{H}_t = \frac{12}{5} \frac{\mathbf{E}\,\mathrm{I}}{c^2 k} v$, by § 176, and, equating these two values, we get

$$\frac{15}{16} \cdot \frac{\mathbf{E}\,\mathrm{I}}{c\,k^2} \cdot u = \frac{12}{5} \frac{\mathbf{E}\,\mathrm{I}}{c^2\,k} v,$$

or

$$u = \frac{64}{25} \cdot \frac{k}{c} \cdot v = \frac{16}{25} \cdot \frac{\mathrm{H}}{\mathrm{A}\,\mathbf{E}} \cdot \frac{3\,c^2 + 2\,k^2}{c}.$$

If, in our preceding example, A is eight square inches, and $\mathbf{E}$ is 24,000,000, u becomes half an inch.

178. **Parabolic Rib with Fixed Ends.** — In this case the deflection will naturally correspond with that of a beam of uniform section, uniformly loaded, and fixed at the ends, as will be seen by comparing the equilibrium curve of Fig. 17, where H from temperature alone acts, with that of such a beam. In Part II., "Bridges," § 99, and Fig. 47, we found that

$$v = \frac{w\,l^4}{384\,\mathbf{E}\,\mathrm{I}} = \frac{w\,c^4}{24\,\mathbf{E}\,\mathrm{I}} = \frac{\mathrm{M}_0\,c^2}{4\,\mathbf{E}\,\mathrm{I}},$$

if M_0 is the bending moment at the middle. Equating this value of v with the one found in § 174, we obtain

$$\mathrm{M}_0 = \frac{\mathrm{I}\,\mathrm{H}\,(3\,c^2 + 2\,k^2)}{\mathrm{A}\,c^2\,k}.$$

The bending moment at the springings will be double this amount, and of the opposite sign.

The deflection produced by a change of temperature will be found by taking the area moment of the semi-segment of the parabola already obtained in § 176, and subtracting the area moment of the rectangle whose height is $\frac{2}{3}k$ and base c.

$$v_t = \frac{\mathrm{H}_t}{\mathrm{E\,I}}\left(\tfrac{5}{12}c^2k - \tfrac{2}{3}ck \cdot \tfrac{1}{2}c\right) = \tfrac{1}{12}\frac{\mathrm{H}_t}{\mathrm{E\,I}}c^2k.$$

Applying the data of the previous example of § 175, we have

$$\mathrm{M}_0 = \frac{25 \times 20 \times 30{,}800}{16 \times 10{,}000 \times 20} = 4.8 \text{ ft. tons at crown},$$

giving 1.92 tons, compression on upper flange and an equal tension on lower flange at crown, and 3.85 tons, tension on upper flange with an equal compression on lower flange, at either springing.

To find such additional length of span for the parabolic rib fixed at the ends, that, when compressed under steady load, it may have no bending moments due to change of form, we pursue again the method of § 177. From § 76,

$$\mathrm{H}_t = \frac{45}{4} \cdot \frac{\mathrm{E\,I}}{ck^2} \cdot tec = \frac{45}{4} \cdot \frac{\mathrm{E\,I}}{ck^2} \cdot \frac{u}{2}.$$

As above,

$$\mathrm{H}_t = \frac{12\,\mathrm{E\,I}}{c^2k}v;$$

therefore

$$u = \frac{32}{15} \cdot \frac{k}{c} \cdot v = \frac{8}{15} \cdot \frac{\mathrm{H}}{\mathrm{A\,E}} \cdot \frac{3c^2 + 2k^2}{c},$$

a quantity five-sixths of that for the rib with hinged ends.

179. **Circular Rib hinged at Ends.** — It is more difficult to obtain the amount of deflection from change of form produced by the compression at each section of a circular rib, even approximately. As the equilibrium polygon for steady load will not deviate much from the axis of the rib, the thrust T may be assumed to vary as secant θ, the inclination of the rib

at successive points to the horizon: hence the shortening of a small portion, $d\,s$, of arc under the thrust will be

$$d\,(s - s') = \frac{\mathrm{T}\,d\,s}{\mathrm{A\,E}} = \frac{\mathrm{H}\,d\,s}{\mathrm{A\,E}} \text{ secant } \theta = \frac{\mathrm{H}\,r}{\mathrm{A\,E}} \cdot \frac{d\,\theta}{\cos\theta};$$

as the section is constant,

$$s - s' = \frac{\mathrm{H}\,r}{\mathrm{A\,E}} \int_{-\beta}^{+\beta} \frac{d\,\theta}{\cos\theta} = \log\ \frac{1 + \sin\beta}{1 - \sin\beta} \cdot \frac{\mathrm{H}\,r}{\mathrm{A\,E}}. \quad (1.)$$

(The symbol *log* denotes the hyperbolic logarithm; to obtain it, multiply the common logarithm by 2.30158.)

As, with a small deflection, the rib will vary but slightly from its original form, let it be assumed to be an arc of a circle after compression. We have then $s - s' = 2\,r\,\beta - 2\,r'\,\beta'$, where r' is the new radius, and β' the new angle subtended by the half-arch. Now

$$r = \frac{c^2 + k^2}{2\,k},\ r' = \frac{c^2 + (k - v)^2}{2\,(k - v)},\ \text{and } \sin\beta' = \frac{c}{r'}.$$

By assuming a value for v, r' and β' can be obtained, and the value of $2\,(r\,\beta - r'\,\beta')$ calculated: if it agrees with the value $s - s'$ of equation (1.), the assumed v is sufficiently near the truth; if not, the process of approximation may be repeated. We may adopt, as a value which will answer very well in many cases, $v = \dfrac{s - s'}{\beta}$. Then

$$v = \frac{\mathrm{H}\,r}{\mathrm{A\,E}\,\beta} \log \frac{1 + \sin\beta}{1 - \sin\beta}.$$

This logarithmic expression may be written as a series,

$$v = \frac{\mathrm{H}\,r}{\mathrm{A\,E}\,\beta} (\sin\beta + \tfrac{1}{3}\sin^3\beta + \tfrac{1}{5}\sin^5\beta, \text{ \&c.}).$$

It was shown in § 36 that the vertical deflections of two beams of the same cross-section, and carrying the same gross load uniformly distributed,—one inclined at an angle i, and the other the horizontal projection of the former,—were in the pro-

portion of $1 : \cos i$. If, then, the load on the horizontal beam is increased in intensity in the ratio $\sec i : 1$, the vertical deflections of the two beams will be the same. We desire to find the amount and distribution of load on a straight beam of the same span as the circular arch, Fig. 58, and the same cross-section, which shall produce the same deflection at the middle. By what has just been stated, the load on any horizontal foot of a straight beam must be to the intensity on an inclined beam as $w \sec \theta$ to w. A small portion of the arch $d\,s \doteq \sec \theta\, d\,x$; hence it follows, that, if the arch is carrying w per horizontal foot over the whole span, a horizontal beam, as above, loaded with the varying intensity $w \sec \theta = w \dfrac{d\,s}{d\,x}$ per foot, will have the same deflection. This load will be the projection of a load of uniform intensity measured along the rib, or the load on the beam is $w\,s$, or $2\,w\,r\,\beta$, in our usual notation.

In any particular case we may easily solve the problem graphically. Lay off 1–2, Fig. 58, equal $w\,.\,\mathrm{A\,B}$; divide A B into a number of equal parts, and 1–2 into the same number, with half-loads at 1 and 2 as usual. Make 2–0 equal to H for this load, and, with 0 as a pole, draw the equilibrium polygon $\mathrm{A}'\,\mathrm{B}'$, which, for an arch of moderate rise, will be a close approximation to a catenary. $\mathrm{C}'\,\mathrm{B}'\,.\,(0\text{–}2)$ will be the desired bending moment M_0, for a deflection found by taking the area moment of $\mathrm{A}'\,\mathrm{B}'\,\mathrm{C}'$ about A', multiplying by 0–2, and dividing by **E I**. Use these values as we did those of § 174. In constructing, increase the length of the rib by (1.) if thought desirable. The values of the following section may be taken if preferred.

180. **Analytical Discussion.** — The exact values may be deduced by the usual process for finding the deflection of a beam. If x is the distance of any point of the beam from one abutment (Fig. 59), β, the angle subtended at the centre by the half-arch, θ, the angle from the crown to any point whose projection is x, and w, the load per foot on the arch, and also at the middle of the beam, then $x = r\,(\sin \beta - \sin \theta)$, $d\,x = -r \cos \theta\, d\,\theta$, the load at any point $= w \sec \theta$ per foot, and load on $d\,x = w \sec \theta\, d\,x$

$= -w\, r \sec\theta \cos\theta\, d\,\theta = -w\, r\, d\,\theta$. The load on one-half of the span is shown in the figure.

$$\text{Load on half-span} = \int_0^c w \sec\theta\, d\,x = w\, r \int_0^\beta d\,\theta = w\, r\, \beta.$$

This expression is the reaction P_1 at the abutment. If x' is the distance from the abutment to any section at which we desire the bending moment, and the corresponding angle is θ', we have the bending moment

$$M = P_1\, x' - \int_0^{x'} (x' - x)\, w \sec\theta\, d\,x$$

$$= w\, r^2 \beta\, (\sin\beta - \sin\theta') - w\, r^2 \int_\beta^{\theta'} (\sin\theta' - \sin\theta)\, d\,\theta$$

$$= w\, r^2\, (\beta \sin\beta + \cos\beta - \theta' \sin\theta' - \cos\theta'),$$

which becomes at the middle

$$M\ (\max) = w\, r^2\, (\beta \sin\beta + \cos\beta - 1) = w\, r\, (c\,\beta - k).$$

Writing the usual expressions for inclination and deflection, and dropping the accents, we have

$$i_x = \int_x^c \frac{M}{E\,I}\, d\,x = -\frac{w\, r^3}{E\,I} \int_0^\theta (\beta \sin\beta + \cos\beta - \theta \sin\theta - \cos\theta) \cos\theta\, d\,\theta$$

$$= -\frac{w\, r^3}{E\,I} (\beta \sin\beta \sin\theta + \cos\beta \sin\theta - \tfrac{3}{4} \sin\theta \cos\theta - \tfrac{3}{4}\theta + \tfrac{1}{2}\theta \cos^2\theta).*$$

The slope at the abutment, when $\theta = \beta$, is $-\frac{w\, r^3}{4\,E\,I} (\beta \sin^2\beta - \beta \cos^2\beta + \sin\beta \cos\beta)$, which, if we remove $\frac{H}{E\,I}$, is the area of the half equilibrium polygon A′ B′ C′ of Fig. 58. The deflection of the centre is

$$v = \int_0^c i\, d\,x = \frac{w\, r^4}{E\,I} \int_0^\beta (\beta \sin\beta \sin\theta + \cos\beta \sin\theta - \tfrac{3}{4} \sin\theta \cos\theta - \tfrac{3}{4}\theta + \tfrac{1}{2}\theta \cos^2\theta) \cos\theta\, d\,\theta$$

$$= \frac{w\, r^4}{E\,I} (\tfrac{1}{3}\beta \sin^3\beta + \tfrac{7}{36} \sin^2\beta \cos\beta - \tfrac{1}{4}\beta \sin\beta - \tfrac{1}{9}\cos\beta + \tfrac{1}{9}).*$$

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* These expressions are reduced. To aid any who desire to prove them, we give the following integrals: $\int \theta \cos\theta\, d\,\theta = \theta \sin\theta + \cos\theta$; $\int \theta \sin\theta \cos\theta\, d\,\theta = -\frac{1}{2}\theta \cos^2\theta + \frac{1}{4} \cos\theta \sin\theta + \frac{1}{4}\theta$; $\int \cos^2\theta\, d\,\theta = \frac{1}{2} \sin\theta \cos\theta + \frac{1}{2}\theta$; $\int \theta \cos^3\theta\, d\,\theta = \theta \cos^2\theta \sin\theta + \frac{7}{9} \cos^3\theta + \frac{2}{3}\theta \sin^3\theta + \frac{2}{3} \sin^2\theta \cos\theta$.

From this expression, by removing $\frac{\mathrm{H}}{\mathrm{EI}}$, we obtain the area moment of A′ B′ C′.

The quantities representing v and M will now be introduced in the equation of § 179: hence we get

$$\frac{\mathrm{H}}{\mathrm{A}\beta}\log\frac{1+\sin\beta}{1-\sin\beta}=\frac{w\,r^3}{18\,\mathrm{I}}(12\,\beta\sin^3\beta+7\sin^2\beta\cos\beta-9\,\beta\sin\beta-4\cos\beta+4).$$

Find the value of M for the special arch, and value of β, and also the value of v. Let $v \div \mathrm{M} = \mathrm{B}\,r^2$; then

$$\mathrm{M}=\frac{\mathrm{H}\,r}{2\,\mathrm{B}\,r^2\,\mathrm{A}\,\mathrm{E}\,\beta}\log\frac{1+\sin\beta}{1-\sin\beta}.$$

If the arch is a semicircle,

$$\mathrm{M}\,(\max)=\tfrac{1}{2}\,w\,r^2\,(\pi-2)\,;\quad i=-\frac{w\,r^3}{4\,\mathrm{EI}}\cdot\frac{\pi}{2};\quad v=\frac{w\,r^4}{36\,\mathrm{EI}}\,(\tfrac{3}{2}\,\pi+4).$$

181. **Circular Rib Fixed at Ends.** — From the method of treating the parabolic rib with fixed ends, as compared with the parabolic rib with hinged ends, we would suggest that the deflection and the bending moments at crown and springing of the circular arch with fixed ends, due to the compression of the rib from H, may be obtained from a drawing like Fig. 58, when 2–0 is made equal to the H of this case, by plotting the closing line of Fig. 27 on the arch of Fig. 58, at the height above A of $r\left(\frac{\sin\beta}{\beta}-\cos\beta\right)$ (see § 105), projecting the points of contraflexure vertically on A′ B′, drawing the horizontal closing line of this equilibrium polygon, and then finding M and v for the beam fixed at the ends.

For circular arches of moderate rise, the treatment for parabolic arches will probably suffice.

CHAPTER XII.

BRACED ARCH WITH HORIZONTAL MEMBER; OTHER SPECIAL FORMS; CONCLUSION.

182. **The Usual Analysis not Applicable.** — The difficulty in the way of a successful application of the usual formula Σ E F . D E $= 0$ for the change of span of the braced arch with horizontal member, of Fig. 60, or, as it is sometimes called, the rib with spandrel bracing, arises from the fact that the *moment of inertia* of successive cross-sections cannot be left out of the equation as a constant. In fact, it varies rapidly; and its amount at any section is unknown until the sizes of the respective pieces are determined. It was shown, in § 72, that **I** must be placed in the denominator of the above formula: and, if not constant, it must come within the sign of summation.

This arch is pivoted at the springings, but continuous at the crown. If it were hinged at the crown by the omission of a piece in either the lower or the upper chord, the thrusts at the abutments could at once be determined by the principles of Chap. II.; and a diagram by the method of Part I., "Roofs," would at once give the stresses in all the pieces for any given load. For the treatment of the case represented in Fig. 60, the following practicable method is offered. It was published in "The Engineer," Feb. 10, 1873, and will also be found in the ninth edition of "The Cyclopædia Britannica," art. "Bridges," where it is attributed to Professor Clerk-Maxwell.

183. **Change of Span from Stress in a Piece.**—From previous statements, we know that the modulus of elasticity **E** is the measure of the extensibility or compressibility of the kind of material to which it refers, so long as the stress does not surpass the elastic limit, and is equal to the quotient of the intensity of the stress on a cross-section divided by the extension or compression of a *unit's* length of the piece in which the stress is exerted. Thus, if l is the length of a piece in inches, A its cross-section in square inches, T the thrust or tension in pounds to which it is exposed, and Δl the change of length produced,

$$\mathbf{E} = \frac{T}{A} \cdot \frac{l}{\Delta l}; \quad \text{or} \quad \Delta l = \frac{T}{\mathbf{E} A} l. \quad (1.)$$

If the piece A of the frame of Fig. 61 is changed in length, and every other piece is unchanged, while the portion of the frame to the right is held firmly in place, the span L of the frame will undergo an alteration Δ L. In this case the motion takes place about the joint opposite to A, and we may write

$$\Delta L : \Delta l = a\,c : a\,b, \quad (2.)$$

or the distance described by the point b for a small displacement around the axis a will be to the horizontal movement of d as the arm $a\,b$ to the arm of d, or $a\,c$. A similar proportion will be true, if one of the lower chord pieces is supposed to alter in length. In case any diagonal is changed in length, as, for instance, $f\,g$, the four-sided figure $e\,f\,i\,g$ must alter to $e\,f\,i'\,g'$ of the sketch below, the point i turning about f as a centre, and the point g about e: hence, for a small displacement, the centre of motion is at the point of meeting, o, of $i\,f$ and $g\,e$ prolonged, which, for this arch, will lie in the upper chord; and the perpendicular p, dropped on the line of the piece, will take the place of $a\,b$ above.

184. **Stress in a Piece from H and P.**—Let t be the stress produced in a member by a horizontal force H acting between the springing points. Then the principle of equality of moments as necessary for equilibrium about the point around

which motion would otherwise begin, and which is no other than the point noticed at the close of the last section, will determine the relation of the forces. A general rule for finding the axis about which rotation will begin is, Make a section which shall cut three pieces only; prolong the lines of two of the pieces until they meet: the moment of the stress in the third piece about that point of meeting will equal the moment of H about the same point. Hence we have, for the piece A

$$t \cdot ab = \mathrm{H} \cdot ac, \text{ or } t = \frac{ac}{ab}\mathrm{H}.$$

Similarly, let t' be the stress produced in A by a vertical force P applied at one springing, while the other end of the frame is held rigidly so that it cannot turn. As the arm of P will be dc, we may write

$$t' \cdot ab = \mathrm{P} \cdot dc, \text{ or } t' = \frac{dc}{ab}\mathrm{P}.$$

The distances dc and ac, being respectively horizontal and vertical, may be denoted in general for any piece by x and y. In order to make the symbol ab of the last section and of this one general, so as to apply to a diagonal as well as a chord piece, let us write for ab the perpendicular p drawn from the axis of rotation upon the action-line of the piece.

Any thrust at the springing having horizontal and vertical components H and P will produce a stress T in the piece, equal to $t + t'$, or

$$\mathrm{T} = \frac{ac \cdot \mathrm{H} + dc \cdot \mathrm{P}}{ab} = \frac{\mathrm{H}y + \mathrm{P}x}{p}. \quad (1.)$$

It is evident that heed must be paid to the kind of stress produced by H and P; thus, in any piece of the top member, H will produce tension and elongation, while P will produce compression and shortening: the reverse will be true of the lower member; how the diagonals are affected will be seen when we come to our application. Appropriate signs, therefore, must be given to the arithmetical values of the stress and alter-

ation of length; thus compression and shortening may be called positive, tension and lengthening, negative.

185. **Formula for H.** — From equations (1.) and (2.), § 183, upon writing y and p, as indicated above, for $a\,c$ and $a\,b$, we get the change of span for any stress, T, in a particular piece,

$$\Delta\,L = \Delta\,l\frac{y}{p} = \frac{T\,y}{p} \cdot \frac{l}{E\,A},$$

or, upon inserting the value of T from equation (1.), last section,

$$\Delta\,L = \frac{H\,y^2 + P\,x\,y}{p^2} \cdot \frac{l}{E\,A}.$$

This same quantity can be calculated for the extensibility due to each member of the frame; and the result will not be altered by the slight yielding of all the others, unless this yielding produces sensible deformation, making appreciable changes in $\frac{x}{p}$ and $\frac{y}{p}$: hence the sum of all the changes of span, or the total change of span, will be

$$H\,\Sigma\frac{y^2}{p^2} \cdot \frac{l}{E\,A} + \Sigma\,P\frac{x\,y}{p^2} \cdot \frac{l}{E\,A}.$$

If the abutments do not yield, this expression is zero. If the span changes, by a yielding of the abutments, so that e is the elongation of span for one ton of H, then the above expression for change of span equals e H. P is the vertical component of the reaction at one abutment, found as for any frame loaded as this arch may be: hence H may be found. If the abutments do not yield, we then obtain

$$H = \frac{\Sigma\,P\frac{x\,y}{p^2} \cdot \frac{l}{E\,A}}{\Sigma\frac{y^2}{p^2} \cdot \frac{l}{E\,A}}. \quad (1.)$$

186. **Application of Method.** — Let a single weight, W, be applied at any one of the top joints of the braced arch, Fig. 60.

Inclined reactions will be produced at each abutment, whose components will be H and P_1 at the left, H and P_2 at the right. The calculations for the resulting stresses in the pieces are then best made as follows: Construct tables of the values $x \div p$ and $y \div p$ for each member of the frame; the method of sections through the opposite joints, or of moments, will answer best for the top and bottom members, and a diagram such as has been drawn for a roof, for the diagonals; assume a cross-section for each member for an assumed probable value of the abutment thrust; make tables of $\frac{x\,y}{p^2} \cdot \frac{l}{\mathbf{E}\,A}$ and $\frac{y^2}{p^2} \cdot \frac{l}{\mathbf{E}\,A}$, or, what is equivalent when all the frame is of one material, so that $\mathbf{E}$ is constant, make tables of $\frac{x\,y\,l}{p^2\,A}$ and $\frac{y^2\,l}{p^2\,A}$. The summations indicated in (1.), § 185, can then be made. In summing $P \cdot \frac{x\,y\,l}{p^2\,A}$, the value P_1 must be used for all pieces to the left of the loaded joint, and P_2 for all pieces to the right of the load. Equation (1.), above, will now give the value of H for this single load.

The process of finding the numerator of (1.) must be repeated for each joint which is loaded. The abutment reactions having thus been found, the stress in each piece will be computed by (1.) § 184, or will be scaled from a diagram drawn as in Part I., "Roofs." If, upon finding the maximum stresses in the pieces, resulting from the steady load and such rolling loads as will have the worst effect, the assumed sections are not strong enough for these stresses, fresh cross-sections must be assumed, and the whole calculation repeated. The change in cross-sections will cause some change in the values of H; but this tentative process need seldom be repeated but once.

187. **Example; Stresses from H and P.**—These processes will probably be rendered more clear by an example. Let the arched frame of Fig. 60 be 120 feet in span, 12 feet rise to the curved member, and 17 feet rise to the straight member, making the depth at mid-span 5 feet. Let the upper member be divided into panels of 10 feet each, and the parabolic or circu-

lar arc into portions of 10.263 feet each.[1] The radius of the curved member will be 156 feet. Let it be desired to design this arched structure to bear a steady load of ten tons per joint of the top member and a travelling load of the same intensity.

If a horizontal line L O is drawn to represent a certain value of H, we may construct Fig. 62 by the method used in Part I., "Roofs," and by scale determine the magnitude of the stress in each piece due to this H, as the *only force*, applied as a thrust at each abutment; all of the stresses being measured as *fractions of* H, and the kind of stress noted. One-half of the diagram is sufficient, as it will be symmetrical. The magnitude of any stress in a top or bottom piece can be readily proved by the method of moments. We may now fill the columns of a table with these ratios which represent $y \div p$, being not only the ratios of the stresses to H, but of the change of span to change of length. Bow's notation is used, and the stresses in one half of the frame will correspond with those in the other half. The sign + denotes compression, the sign — denotes tension.

VALUES OF $\frac{y}{p}$.

B O —0.272	A L +1.203	O A —0.444	A B +0.450
D O —0.639	C L +1.520	B C —0.478	C D +0.480
F O —1.117	E L +1.927	D E —0.500	E F +0.502
I O —1.678	G L +2.427	F G —0.484	G I +0.488
K O —2.185	J L +2.942	I J —0.384	J K +0.386
N O —2.400	M L +3.293	K M —0.153	M N +0.154

In the same way a diagram constructed upon a vertical line which represents P_1, Fig. 63, will give the stresses in the several pieces caused by this vertical force only, applied in an upward direction at the left abutment, while the right end is held rigidly in place by fixing the end brace in position. This figure will not be symmetrical, and therefore all the pieces must be entered in the table. P_2 at the right abutment, in place of P_1 at the left, will reverse the table, B′ O taking the place of B O, &c. The ratio of these stresses to P will give $x \div p$.

[1] If the arc is parabolic, the length of a piece will be 10.268 feet. The difference is not material for our example.

VALUES OF $\frac{x}{p}$.

B O	+ 0.718	A L	— 0.354	O A	+1.178	A B	—1.189
D O	+ 1.872	C L	— 1.341	B C	+1.505	C D	—1.780
F O	+ 3.662	E L	— 2.833	D E	+1.872	E F	—1.879
I O	+ 6.226	G L	— 4.996	F G	+2.214	G I	—2.232
K O	+ 9.319	J L	— 7.787	I J	+2.341	J K	—2.353
N O	+12.000	M L	—10.655	K M	+1.907	M N	—1.920
K′ O	+13.163	M′ L	—12.592	N M′	+0.833	M′ K′	—0.827
I′ O	+12.675	J′ L	—12.978	K′ J′	—0.371	J′ I′	+0.309
F′ O	+11.283	G′ L	—12.134	I′ G′	—1.212	G′ F′	+1.202
D′ O	+ 9.698	E′ L	—10.767	F′ E′	—1.657	E′ D′	+1.664
B′ O	+ 8.260	C′ L	— 9.387	D′ C′	—1.876	C′ B′	+1.880
		A′ L	— 8.139	B′ A′	—1.367	A′ O	fixed.

188. **Computation of Tables.** — We may now write a table for $\frac{y^2 l}{p^2}$, and another for $\frac{x y l}{p^2}$, for each piece of the frame. The first table, involving squares, will be positive throughout. The lengths of the horizontal and rib pieces will be multiplied by the footing of their respective columns to save labor; but the lengths of the diagonals are carried in as indicated.

VALUES OF $\frac{y^2 l}{p^2}$.

B O	0.074	A L	1.447	O A	0.197 × 17.72 =	3.491	A B	0.202 × 14.08 =	2.844
D O	0.408	C L	2.310	B C	0.228 × 14.33	3.267	C D	0.230 × 11.17	2.569
F O	1.248	E L	3.713	D E	0.250 × 11.58	2.895	E F	0.252 × 9.15	2.306
I O	2.816	G L	5.890	F G	0.234 × 9.67	2.263	G I	0.238 × 7.75	1.844
K O	4.774	J L	8.655	I J	0.147 × 8.25	1.213	J K	0.149 × 7.17	1.068
N O	5.760	M L	10.844	K M	0.023 × 7.50	0.172	M N	0.024 × 7.07	0.170
	15.080 × 10		32.859			13.301			10.801
	9.320 × 10		2			2			2
	244.000		65.718 × 10.263 = 674.46			26.602			21.602

Summing these columns, and doubling for the whole arch, we obtain $244.00 + 674.46 + 26.60 + 21.60 = 966.66 = \Sigma . \frac{y^2 l}{p^2}$. If, in the first trial, all the sections are supposed equal, A may be omitted from (1.), § 185, and 966.66 becomes the denominator of that expression.

We next compute the following table, and multiply by the length of each piece as we advance. It will be convenient to add other columns, marked Σ, containing successive summations of the factors for each set of pieces, as these numbers will be used in turn. The *summations* are all *negative*, as will be readily seen, and hence the sign — is omitted.

VALUES OF $\frac{x\,y\,l}{p^2}$.

	Σ		Σ		Σ		Σ
B O — 1.95	1.95	A L — 4.37	4.37	O A — 9.27	9.27	A B — 7.53	7.53
D O — 11.96	13.91	C L — 20.92	25.29	B C —10.30	19.57	C D — 9.54	17.07
F O — 40.90	54.81	E L — 56.05	81.34	D E —10.84	30.41	E F — 8.63	25.70
I O —104.47	159.28	G L —124.44	205.78	F G —10.37	40.78	G I — 8.44	34.14
K O —203.62	362.90	J L —235.11	440.89	I J — 7.42	48.20	J K — 6.51	40.65
N O —288.00	650.90	M L —360.10	800.99	K M — 2.19	50.39	M N — 2.09	42.74
K′ O —287.61	938.51	M′ L —425.55	1226.54	N M′ + 0.95	49.44	M′ K′ + 0.10	42.64
I′ O —212.69	1151.20	J′ L —391.85	1618.39	K′ J′ — 1.17	50.61	J′ I′ — 0.85	43.49
F′ O —126.03	1277.23	G′ L —302.23	1920.62	I′ G′ — 5.68	56.29	G′ F′ — 4.55	48.04
D′ O — 61.97	1339.20	E′ L —212.94	2133.56	F′ E′ — 9.59	65.88	E′ D′ — 7.64	55.68
B′ O — 22.47	1361.67	C′ L —146.43	2280.00	D′ C′ — 12.85	78.73	C′ B′ — 10.07	65.75
		A′ L —100.48	2380.48	B′ A′ — 10.76	89.49	A′ O fixed.	——

189. **Values of H.** — The calculations for H can now be proceeded with, and they are given below. An explanation of one computation will suffice for all. If a weight W is placed on the third upper joint from the left, the vertical component of the left abutment reaction, P_1, is $\frac{19}{24}$ W. Then, for the two pieces of the upper chord to the left we have $\Sigma P_1 \frac{x\,y}{p^2} l = 13.91\,P_1$; for the two pieces of the rib to the left, we get $25.29\,P_1$, and, for the five web-members to the left, $30.41 + 17.07 = 47.48\,P_1$. On the right of the weight, the nine remaining pieces of the upper chord give $\Sigma P_2 \frac{x\,y}{p^2} l = 1277.23\,P_2$, which will be found opposite F′ O, as the vertical force is now applied at the right end; for the ten pieces of the rib we find $2133.56\,P_2$, and for the rest of the web to E F we find opposite E′ F′ and F′ G′, for the reason

just stated, $65.88 + 48.04 = 113.92$ P_2. As the piece E L, below the weight, is acted upon by P_1 on one side, and P_2 on the other, it makes no difference whether it is considered to lie to the left or the right of the loaded point. Adding up the respective numbers, multiplying one by $\frac{19}{24}$, and the other by $\frac{5}{24}$, adding, and dividing by $\Sigma \frac{y^2}{p^2} l = 966.66$, we get $H = 0.831$ W for a load on the third joint only. The divisor $966.66 \times 24 = 23{,}200$, is used.

VALUES OF H.

W on 1st Joint.		W on 2d Joint.		W on 3d Joint.	
0	1361.67	1.95	1339.20	13.91	1277.23
0	2380.48	4.37	2280.00	25.29	2133.56
9.27	89.49	19.57	78.73	30.41	65.88
9.27	65.75	7.53	55.68	17.07	48.04
23	3897.39	33.42	3753.61	86.68	3524.71
213.21		21	3	19	5
3897.39		701.82	11260.83	1646.92	17623.55
41.1060÷232=.177 W		11260.83		17623.55	
		119.6265÷232=.516 W.		192.7047÷232=831 W.	

W on 4th Joint.		W on 5th Joint.		W on 6th Joint.	
54.81	1151.20	159.28	938.51	362.90	650.90
81.34	1920.62	205.78	1618.39	440.89	1226.54
40.78	56.29	48.20	50.61	50.39	49.44
25.70	43.49	34.14	42.64	40.65	42.74
202.63	3171.60	447.40	2650.15	894.83	1969.62
17	7	15	9	13	11
3444.71	22201.20	6711.00	23851.35	11632.79	21665.82
22201.20		23851.35		21665.82	
256.4591÷232=1.105 W.		305.6235÷232=1.317 W.		333.0861÷232=1.436W.	

Having completed the computations for six joints, we add the H's, and multiply by two, obtaining 10.764 W as the value of H for an entire load of W on each upper joint.

190. **Diagrams and Table of Stresses for Equal Cross-sections.** — We may now draw a diagram for a single load W on any one joint, plotting the reactions, just obtained, and proceeding by the method of Part I., "Roofs," Fig. 21. Six diagrams, four of which are drawn, the scale being too small to make the other two clear, Fig. 64, will give all the stresses, as, by symmetry, loads on the right will cause stresses in pieces marked with unaccented letters equal to those now found in pieces marked with accents. The stresses are scaled in tons, tabulated, and marked with their proper signs, in the following table. They might be calculated by (1.), § 184, if preferred, and their sum might be checked by a diagram for complete load. The sums of the respective compressions and tensions are written below, and in the next line are found the differences of these quantities, or the stresses from steady load, marked S. L. Upon adding to these latter the tensions or compressions first referred to, we obtain the maximum stresses in the pieces for a moving load of the same intensity.

It will be seen that the horizontal member is always compressed; the curved rib may have at times a little tension in its middle portion, but the larger part of it is always compressed; the web members are struts and ties alternately, until we reach J K; the pieces from there to the middle may be exposed to a reversal of stress.

191. **Sections proportioned to Stresses.** — Guided by these stresses, we will now assume sections of the different pieces, which shall vary approximately as do the stresses just found. Of the web members, those under compression are intended to be proportionately heavier than those in tension, as they will not safely resist so large a unit stress. The assumed ratio of the sections is marked on the figure. The quantities $\frac{y^2}{p^2} \cdot \frac{l}{A}$ and $\frac{x\,y}{p^2} \cdot \frac{l}{A}$ are now found anew by simply dividing the previous similar quantities by the section ratios just referred to. The results follow on p. 184. $\Sigma \frac{y^2}{p^2} \cdot \frac{l}{A}$ is now 161.18.

STRESSES IN PIECES, ALL CROSS-SECTIONS EQUAL.

Load on	BO.	DO.	FO.	IO.	KO.	NO	AL.	CL.	EL.	GL.	JL.	ML.
1st.	+0.30	+0.30	+0.28	+0.24	+0.17	+0.09	—0.13	—0.13	—0.10	—0.07	—0.01	+0.07
2d.	+0.49	+0.89	+0.85	+0.74	+0.54	+0.29	+0.30	—0.39	—0.35	—0.25	—0.08	+0.14
3d.	+0.34	+0.96	+1.43	+1.26	+0.95	+0.53	+0.70	+0.17	—0.69	—0.57	—0.31	+0.06
4th.	+0.21	+0.62	+1.36	+1.85	+1.43	+0.86	+1.07	+0.72	+0.11	—0.89	—0.56	—0.04
5th.	+0.09	+0.33	+0.82	+1.68	+2.06	+1.34	+1.37	+1.15	+0.73	+0.02	—1.07	—0.44
6th.	0.00	+0.10	+0.38	+0.97	+1.91	+2.05	+1.53	+1.43	+1.20	+0.73	—0.07	—1.16
7th.	—0.06	—0.06	+0.07	+0.44	+1.13	+2.05	+1.54	+1.52	+1.40	+1.12	+0.56	—0.26
8th.	—0.09	—0.14	—0.10	+0.12	+0.61	+1.34	+1.45	+1.47	+1.45	+1.30	+0.93	+0.32
9th.	—0.09	—0.16	—0.16	—0.03	+0.31	+0.86	+1.22	+1.27	+1.29	+1.21	+0.98	+0.52
10th.	—0.07	—0.13	—0.16	—0.08	+0.14	+0.53	+0.90	+0.95	+0.97	+0.93	+0.78	+0.46
11th	—0.05	—0.09	—0.10	—0.07	+0.06	+0.29	+0.55	+0.60	+0.62	+0.62	+0.53	+0.37
12th.	—0.02	—0.03	—0.04	—0.03	0.00	+0.09	+0.19	+0.20	+0.22	+0.21	+0.19	+0.15
Σ +	1.43	3.20	5.19	7.30	9.31	10.32	10.82	9.48	7.99	6.14	3.97	2.09
Σ —	0.38	0.61	0.56	0.21	0.00	0.00	0.13	0.52	1.14	1.78	2.10	1.90
S. L.	+1.05	+2.59	+4.63	+7.09	+9.31	+10.32	+10.69	+8.96	+6.85	+4.36	+1.87	+0.19
Max.	+2.48	+5.79	+9.82	+14.39	+18.62	+20.64	+21.51	+18.44	+14.84	+10.50	+5.84	+2.28
											—0.23	—1.71

Load on	OA.	AB.	BC.	CD.	DE.	EF.	FG.	GI.	IJ.	JK.	KM.	MN.
1st.	+1.05	+0.01	—0.01	+0.01	—0.03	+0.03	—0.04	+0.04	—0.06	+0.06	—0.06	+0.06
2d.	+0.80	—0.82	+1.07	+0.02	—0 07	+0.07	—0.09	+0.09	—0.16	+0.16	—0.18	+0.19
3d.	+0.58	—0.58	+0.81	—0.82	+1.07	+0.07	—0.14	+0.15	—0.25	+0.25	—0.29	+0.30
4th.	+0.33	—0.34	+0.53	—0.54	+0.77	—0.79	+1.04	+0.17	—0.32	+0.33	—0.42	+0.42
5th.	+0.16	—0.16	+0.32	—0.33	+0.53	—0.54	+0.76	—0.78	+0.95	+0.39	—0.52	+0.52
6th.	0.00	0.00	+0.14	—0.15	+0.31	—0.32	+0.51	—0.52	+0.72	—0.74	+0.84	+0.60
7th.	—0.06	+0.06	+0.03	—0.03	+0.15	—0.16	+0.33	—0.34	+0.52	—0.55	+0 65	—0.66
8th.	—0.13	+0.13	—0.04	+0.04	+0.04	—0.04	+0.18	—0.19	+0.37	—0.38	+0.51	—0.53
9th.	—0.13	+0.14	—0.07	+0.07	—0.02	+0.02	+0.11	—0.12	+0.25	—0.26	+0.38	—0.39
10th.	—0.10	+0.10	—0.07	+0.07	—0.02	+0.02	+0.07	—0.07	+0.17	—0.18	+0.27	—0.28
11th.	—0.07	+0.08	—0.05	+0.05	—0.03	+0.03	+0.02	—0.02	+0.09	—0.09	+0.15	—0.15
12th.	—0.02	+0.02	—0.01	+0.01	0.00	0.00	+0.01	—0.01	+0.02	—0.02	+0.05	—0.05
Σ +	2.92	0.54	2.90	0.27	2.87	0.24	3.03	0.45	3.09	1.19	2.85	2.09
Σ —	0.51	1.90	0.25	1.87	0.17	1.85	0.27	2.05	0.79	2.22	1.47	2.06
S. L.	+2.41	—1.36	+2.65	—1.60	+2.70	—1.61	+2.76	—1.60	+2.30	—1.03	+1.38	0.00
Max.	+5.33		+5.55		+5.57		+5.79		+5.39	+0.16	+4.23	+2.09
		—3.26		—3.47		—3.46		—3.65		—3.25	—0.09	—2.06

Values of $\frac{y^2}{p^2} \cdot \frac{l}{A}$.

B O	0.296	A L	0.069	O A	0.582	A B	0.948	
D O	0.680	C L	0.128	B C	0.544	C D	0.642	15.971
F O	1.248	E L	0.248	D E	0.483	E F	0.577	134.527
I O	1.877	G L	0.535	F G	0.377	G I	0.461	4.544
K O	2.513	J L	1.236	I J	0.243	J K	0.356	6.138
N O	2.743	M L	4.338	K M	0.043	M N	0.085	161.180
	9.357		6.554		2.272		3.069	24
	6.614		2		2		2	3868.320
	15.971		13.108 × 10.263		4.544		6.138	

Values of $\frac{x\,y}{p^2} \cdot \frac{l}{A}$.

		Σ			Σ			Σ			Σ
B O	− 0.78	0.78	A L	− 0.21	0.21	O A	−1.54	1.54	A B	−2.51	2.51
D O	− 1.99	2.77	C L	− 1.16	1.37	B C	−1.72	3.26	C D	−2.38	4.89
F O	− 4.09	6.86	E L	− 3.74	5.11	D E	−1.81	5.07	E F	−2.16	7.05
I O	− 6.96	13.82	G L	− 11.31	16.42	F G	−1.73	6.80	G I	−2.11	9.16
K O	−10.72	24.54	J L	− 33.59	50.01	I J	−1.48	8.28	J K	−2.17	11.33
N O	−13.71	38.25	M L	−144.04	194.05	K M	−0.55	8.83	M N	−1.05	12.38
K′O	−15.14	53.39	M′ L	−170.22	364.27	N M′	+0.48	8.35	M′K′	+0.02	12.36
I′ O	−14.18	67.57	J′ L	− 55.98	420.25	K′ J′	−0.39	8.74	J′ I′	−0.17	12.53
F′O	−12.60	80.17	G′ L	− 27.48	447.73	I′ G′	−1.42	10.16	G′ F′	−0.76	13.29
D′O	−10.33	90.50	E′ L	− 14.20	461.93	F′E′	−2.40	12.56	E′D′	−1.27	14.56
B′O	− 8.99	99.49	C′ L	− 8.13	470.06	D′ C′	−3.21	15.77	C′B′	−1.68	16.24
			A′ L	− 4.78	474.84	B′ A′	−3.58	19.35	A′O′ fixed.		

The above *summations* are negative.

Next follow, as before, the computations of H (p. 185).

It will be seen that the change in the sections of the pieces has made but little change in the values of H; the thrust now being 10.820 W for a steady load of W on each joint. We may therefore proceed to draw anew the diagrams for a single load W on any one joint, or we may, by the use of lines of another color, alter the figures already drawn. As H has been changed so little, the new stresses will determine the final

VALUES OF H.

W on 1st Joint.		W on 2d Joint.		W on 3d Joint.	
0.00	99.49	0.78	90.50	2.77	80.17
0.00	474.84	0.21	470.06	1.37	461.93
1.54	19.35	3.26	15.77	5.07	12.56
1.54	16.24	2.51	14.56	4.89	13.29
23	609.92	6.76	590.89	14.10	567.95
35.42		21	3	19	5
609.92		141.96	1772.67	267.90	2839.75
645.34÷3868=.167 W.		1772.67		2839.75	
		1914.63÷3868=.495 W.		3107.65÷3868=.803 W.	

W on 4th Joint,		W on 5th Joint.		W on 6th Joint.	
6.86	67.57	13.82	53.39	24.54	38.25
5.11	447.73	16.42	420.25	50.01	364.27
6.80	10.16	8.28	8.74	8.83	8.35
7.05	12.53	9.16	12.36	11.33	12.38
25.82	537.99	47.68	494.74	94.71	423.25
17	7	15	9	13	11
438.94	3765.93	715.20	4452.66	1231.23	4655.75
3765.93		4452.66		4655.75	
4204.87÷3868=1.087W.		5167.86÷3868=1.336 W.		5886.98÷3868=1.522 W.	

dimensions of the pieces. A sample of the stresses obtained in the upper chord is given below for comparison.

	B O.	D O.	F O.	I O.	K O.	N O.
Σ +	1.45	3.18	5.10	7.08	9.23	10.20
Σ —	0.42	0.63	0.51	0.07	0.00	0.00
S. L.	1.03	2.55	4.59	7.01	9.23	10.20
Max.	+2.48	+5.73	+9.69	+14.09	+18.46	+20.40

A certain allowance in section may be made for the stresses from change of temperature, or the effect of the change of length in each piece may be worked out separately.

192. **Bracing with Vertical Struts.** — The bracing of the arch just described is of the Warren or triangular type. The design of Fig. 65 has been used with success, is probably more economical of material, and is, in our judgment, more pleasing to the eye. The inclined braces are ties, and the introduction of the counters at the crown obviates the reversal of stress in the braces. When the upper member approaches the curved member closely at the crown, the web may be made of a plate for a distance of two panels: sometimes the two members are brought into contact at the crown.

193. **Cast-Iron Arch as a Breast-Summer.** — Builders sometimes employ a cast-iron member, shaped like Fig. 66, for spanning openings of considerable size, and carrying the weight of a brick wall. Aside from the fact that cast-iron in large masses is of very uncertain strength, by reason of internal stresses produced by contraction in cooling, an additional element of uncertainty is introduced by the method of constructing these ribs. The thrust of the arch is resisted by a wrought-iron rod, represented by a straight line in the figure, which, in place of being fastened by bolts or nuts, is fitted into recesses in the casting at its ends. In order to have the rod tight, it is made shorter than the distance between bearings, then heated, and shrunk into place. The rod is therefore under an initial tension, and the rib under initial compression, both of which are likely to be of uncertain amount, and detrimental; for, when the arch is loaded, its horizontal thrust will be added to the tension in the bar, and the compression of the rib will be increased. As, however, the bar elongates under the pull, it would be well, were it possible, to have the bar so much shorter than the normal span of the arch, that the value of H proper to the arch under the proposed load should elongate the rod to that normal span; then the initial bending moments produced in the rib by shrinking on the rod will be removed. It would seem possible, by a careful measurement of the extension of the rod between two marks some ten or twenty feet apart, especially if the stretch has been previously tested, to determine the initial tension.

If the arch is well built into the masonry at the ends, and if the bearings are long, the rib may be considered as fixed at the ends. If not so built, and in preliminary testing on two supports under an applied weight, the rib must be considered as pivoted at the ends. From the small rise, such arches may be assumed, in either case, to be parabolic. In testing, therefore, under a single weight W applied at the middle, by § 40 $H = \frac{25}{64}\frac{c}{k}W$. At that time temporary bearings ought to be placed at A to prevent the arch from bearing at C when loaded. Under the load of the wall, unless the latter is cut by large openings, so that a pier concentrates the weight on a small portion of the rib, there will be no bending moments, as the load is uniformly distributed.

194. **Gothic Rib for Roofs.** — The rib which supports the roof of the Grand Central Depot in New-York City is probably circular, and will be analyzed readily by the principles already laid down; but the Gothic rib requires some special treatment. Fig. 67 is a sketch of the rib which sustains the roof over the train-house of the Boston and Providence Railroad Depot in Boston, Mass. The span is 125 feet between walls, and the height is 55 feet to the axis of the rib. As height impresses one more than horizontal distance, it is evident that this roof appears lofty when viewed from the inside. In order to give height quickly near the walls, the half-rib is struck with two radii, as indicated in the figure. The lower portion is built with a solid web; while most of the upper portion has a uniform depth of three feet. If the junction at the crown or apex of the roof allows any movement, if the ribs can rock or turn on castings at their bases, and if they are independent of the side walls, they may be treated as hinged at three points, and discussed like any three-hinged arch. If there is no opportunity for movement at the bases, and especially if the ribs abut closely against the side walls and buttresses, while still a joint is provided at the crown, the condition of invariability of span must be applied, and also the condition that the deflection of

the crown when measured by area moments from the tangent at one abutment shall equal the deflection of the crown from the tangent at the other abutment. The integration will then be between limits which will appear from the discussion of the third supposition.

The rib may be fixed at the ends and crown, and will then offer a troublesome case for treatment by reason of the great depth at the haunches, unless we assume that it is well buttressed by the wall. In this case, the portion below the top of the wall and the wall itself will act as an abutment; and, as it will only require a moderate tension in the inside flange at the springing to resist the overturning moment, such an assumption seems entirely warrantable. Above the wall, then, some 25 feet high, where the horizontal mark is made on the left-hand side, we assume the springing line of the arch, and consider the remainder as a rib fixed at the ends, and continuous at the crown. In applying the conditions for a rib with fixed ends to this case, we must change the derived equations, as the curve is not continuous at the crown. A parabola drawn through the middle of the depth of the rib at crown, springing, and a third point near the upper end of the straight portion of the rafter, will agree very closely with the axis of the rib throughout. We must first determine k and c for this parabola. In Fig. 68 let h be the height or rise of the arch at the apex, a the horizontal distance from h to the point where the parabola would become horizontal; then

$$h = \frac{k}{c^2}(c^2 - a^2); \quad \text{or} \quad k = h\,\frac{c^2}{c^2 - a^2}.$$

For another ordinate h', distant $c - a'$ from the springing, we write

$$k = h'\,\frac{c^2}{c^2 - a'^2}.$$

In this case $c - a = 55.75$ feet, $h = 30.3$ feet, $c - a' = 22.5$ feet, and $h' = 17$ feet: hence we find that $k = 31.68$ feet, $c = 70.48$ feet, and $a = 14.73$ feet.

In place of performing the integrations of §§ 58–59 between the limits there given, we must omit or subtract from the equations the integrals between the limits $+a$ and $-a$, as this portion is cut out of the parabola. Thus the equation (1.) of § 58 will be written

$$\int_0^{2c} \mathrm{D\,E}^2 - \int_{c-a}^{c+a} \mathrm{D\,E}^2 = \int_0^{c+b} \mathrm{D\,F\,.\,D\,E} - \int_{c-a}^{c+a} \mathrm{D\,F\,.\,D\,E} + \int_0^{c-b} \mathrm{D\,F\,.\,D\,E}.$$

As limits $c+a$ and $c-a$ will yield terms similar to limits $c+b$ and $c-b$, the subtractive quantities above can be written from inspection of (2.), § 58, and (2.), § 39. A similar treatment of the other equations of condition will be required. The solution will then proceed as usual.

If the weight at the apex of the roof, arising from the ventilator, &c., is sufficiently great, it will take the place of the omitted portion of breadth $2\,a$, so that the rib will be very nearly in equilibrium under steady load.

195. **Remarks on Designing.**—The examples which have been given in the preceding pages will indicate the steps to be pursued in working out a specific design. The type of structure having been determined upon, the moving load must be taken of an intensity in harmony with the position of the bridge, or we must decide upon the weight of snow and pressure of wind to which the roof will be liable. The dead weight of the structure must then be assumed, of such an amount as our judgment and experience dictate, to be afterwards verified and corrected from the actual sections. The abutment reactions and bending moments from the applied forces will then be found, after which, stress diagrams may be constructed, or equilibrium polygons drawn; from the first we obtain stresses directly, as in Part I.; from the second, bending moments, with shears and direct thrusts, from which the stresses in the several pieces will be found, as in Part II. The first method is probably the shorter for roofs, unless the rib is solid, or has a plate web, as all of the load of one kind may be included at one operation: the second method will be preferred where a moving load has to be

considered. The stresses will then be tabulated, and the maximum compression and tension on each piece found.

A point which may call for a little explanation is illustrated by Fig. 69. We desire to draw a stress diagram for an arched rib, which is fixed at the end A B, the equilibrium curve beginning with the line G D, and the bending moment at A B being T . p, or its equivalent. The flanges at A and B will transmit direct force only: therefore decompose T into C, the compression parallel to the flanges, at the springing, and F, the shear at right angles. Then, by moments about A, Thrust at $\mathrm{B} \cdot \mathrm{A\,B} = \mathrm{C} \cdot \mathrm{A\,G}$, or Thrust at $\mathrm{B} = \frac{\mathrm{C} \cdot \mathrm{A\,G}}{\mathrm{A\,B}}$; by moments about B, Tension at $\mathrm{A} = \frac{\mathrm{C} \cdot \mathrm{B\,G}}{\mathrm{A\,B}}$. The shear F will be resisted either at A or B, depending upon which of the braces is designed to carry it: if the braces are ties, it must pass through the one at A. Thus we obtain the forces with which to begin the stress diagram. In case of a hinge at the abutment, the point G is found midway between A and B, and there will be $\frac{1}{2}$ C, compression, at each flange. F will be found in the proper brace as above.

The arched rib must be thoroughly stayed laterally; for so much of either flange as is compressed is in unstable equilibrium; between lateral stays, the breadth of a compressed flange must be determined from the formulæ for columns. For a few formulæ and directions for detailing, see the closing chapter of Part I.

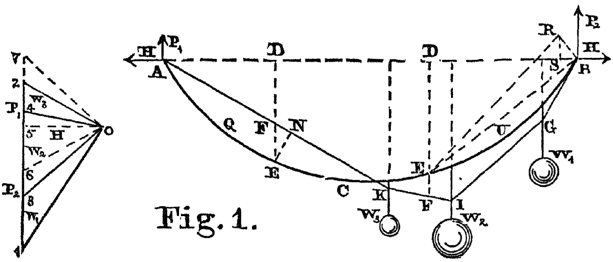

Fig. 1.

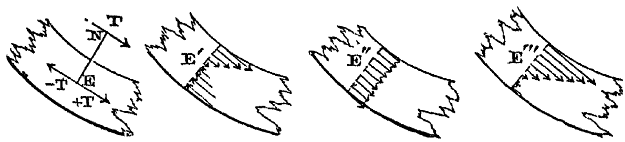

Fig. 2.

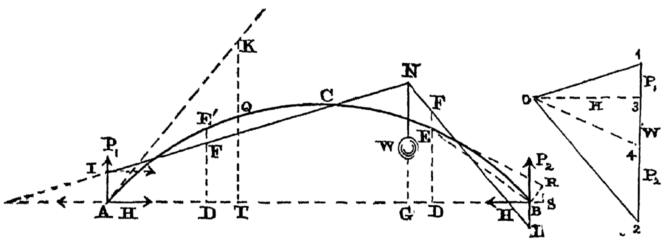

Fig. 3.

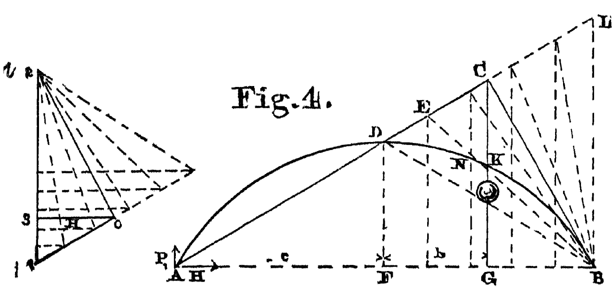

Fig. 4.

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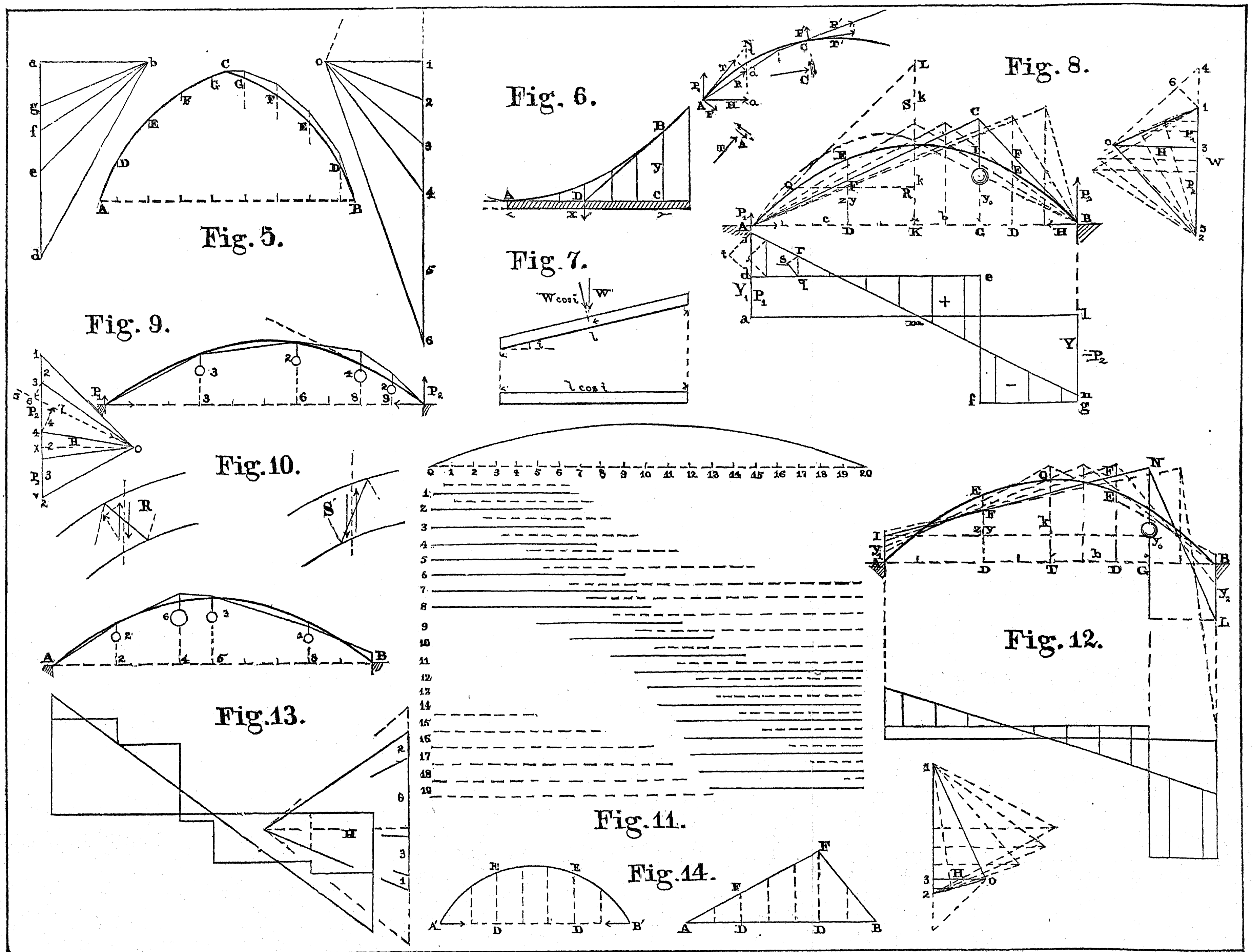
Fig. 5.
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Fig. 7.
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Fig. 14.

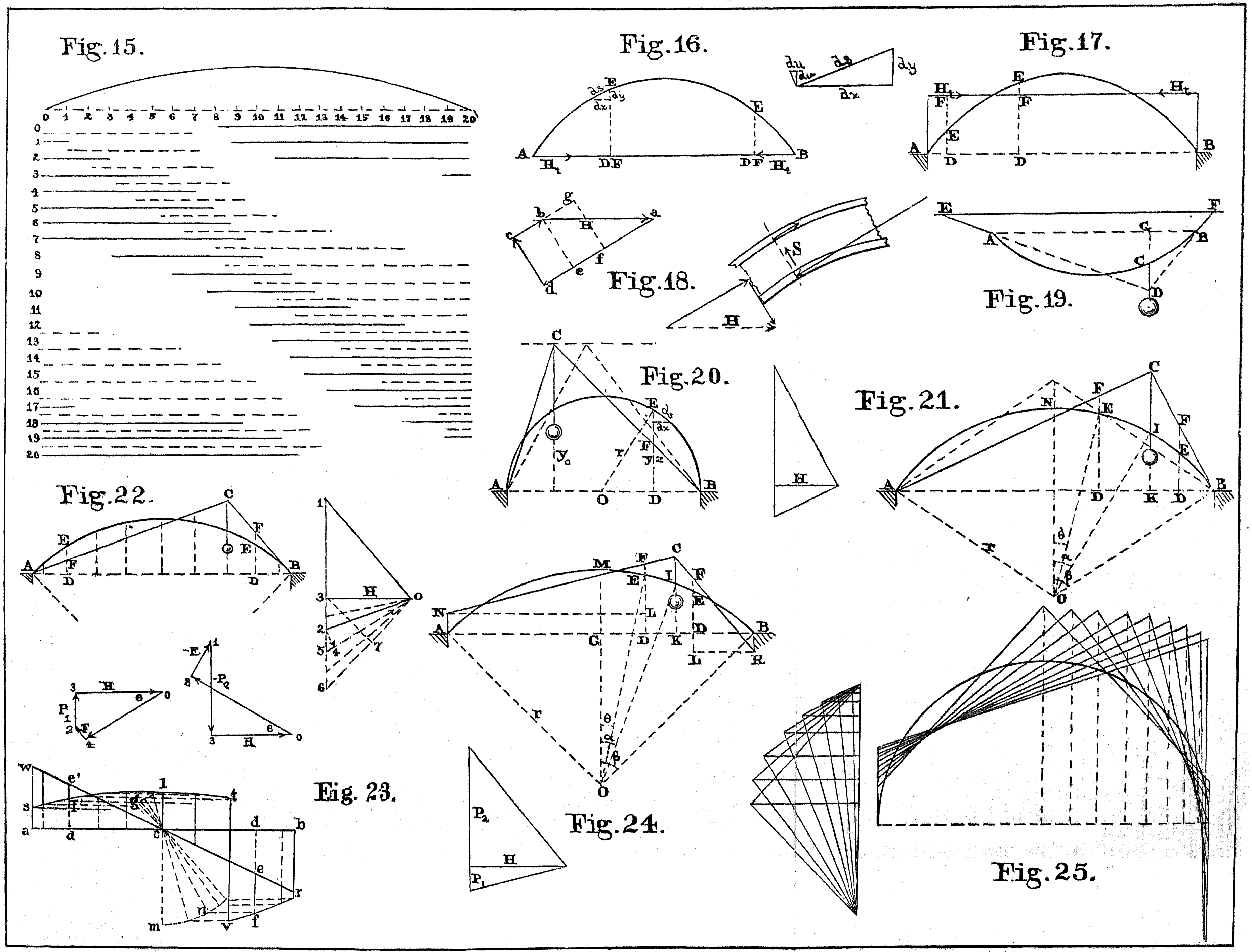
Fig. 15.
Fig. 16.
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Fig. 25.

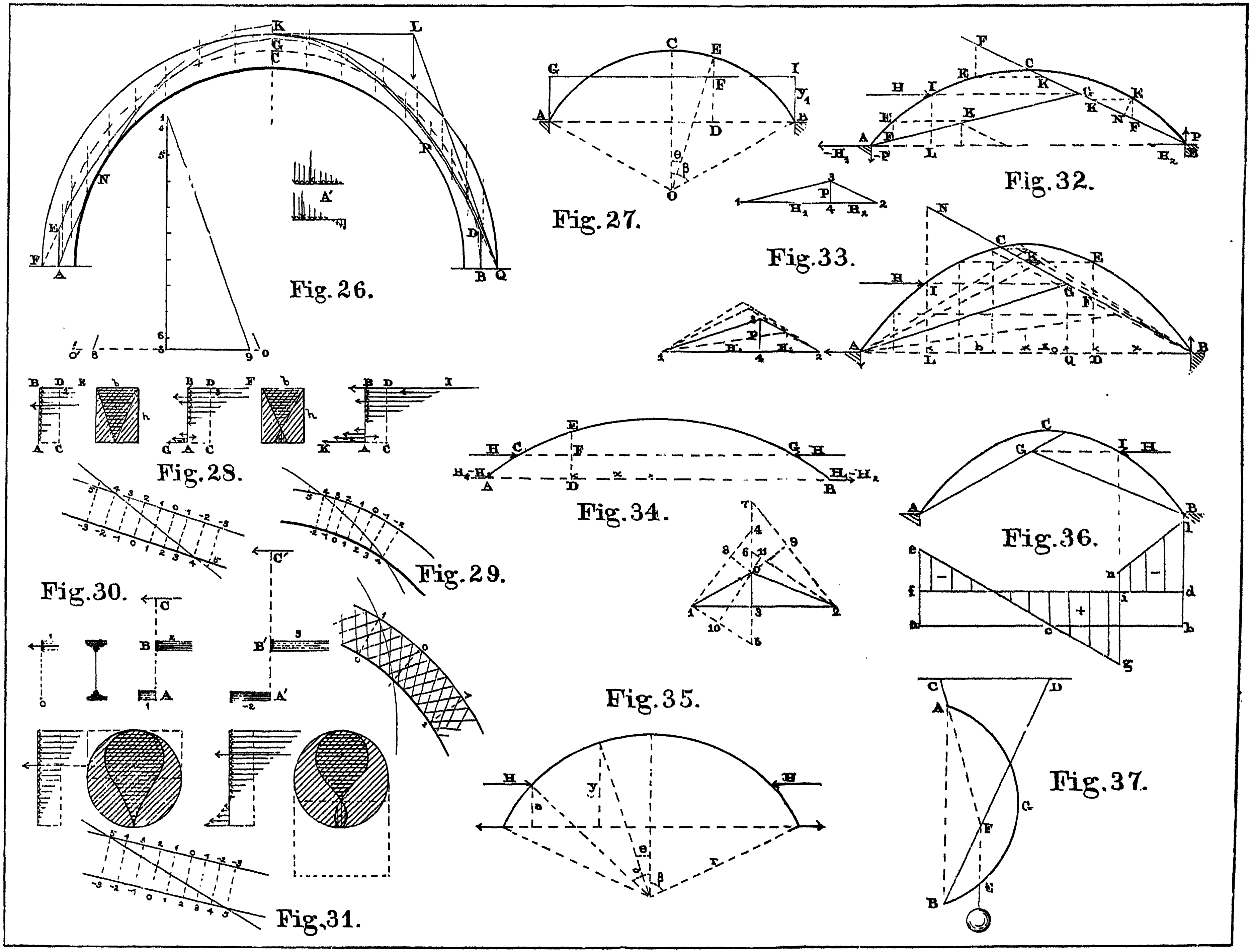

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

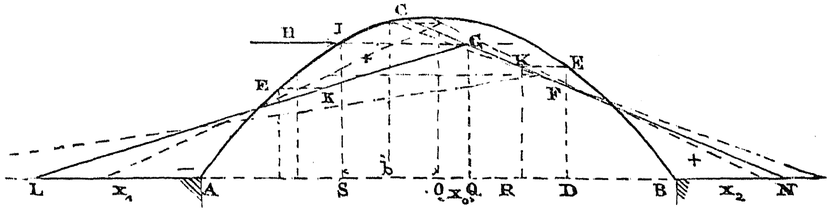

Fig. 38.

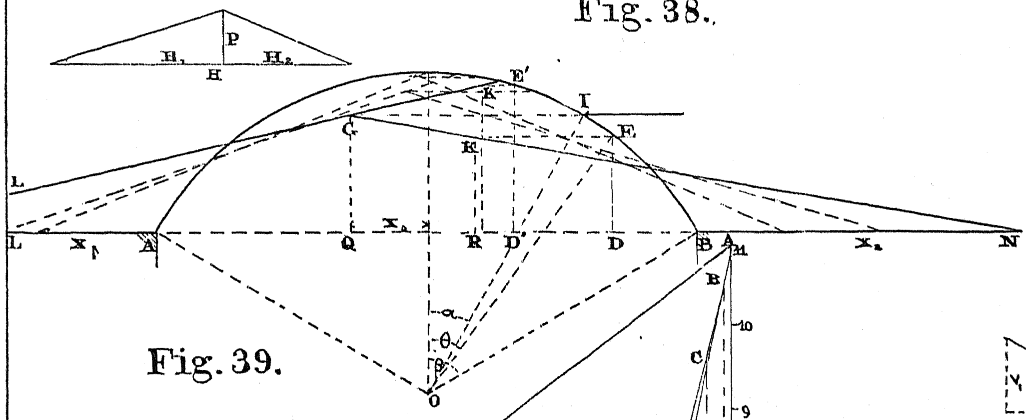

Fig. 39.

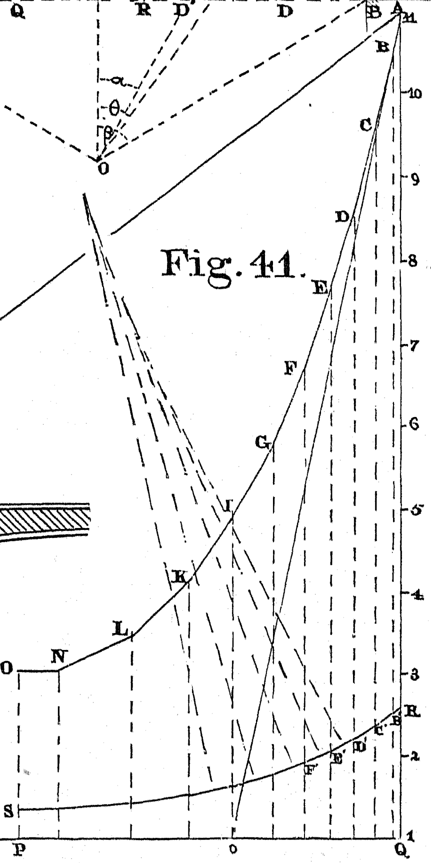

Fig. 41.

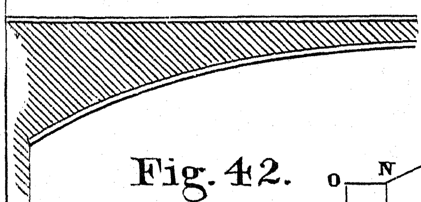

Fig. 42.

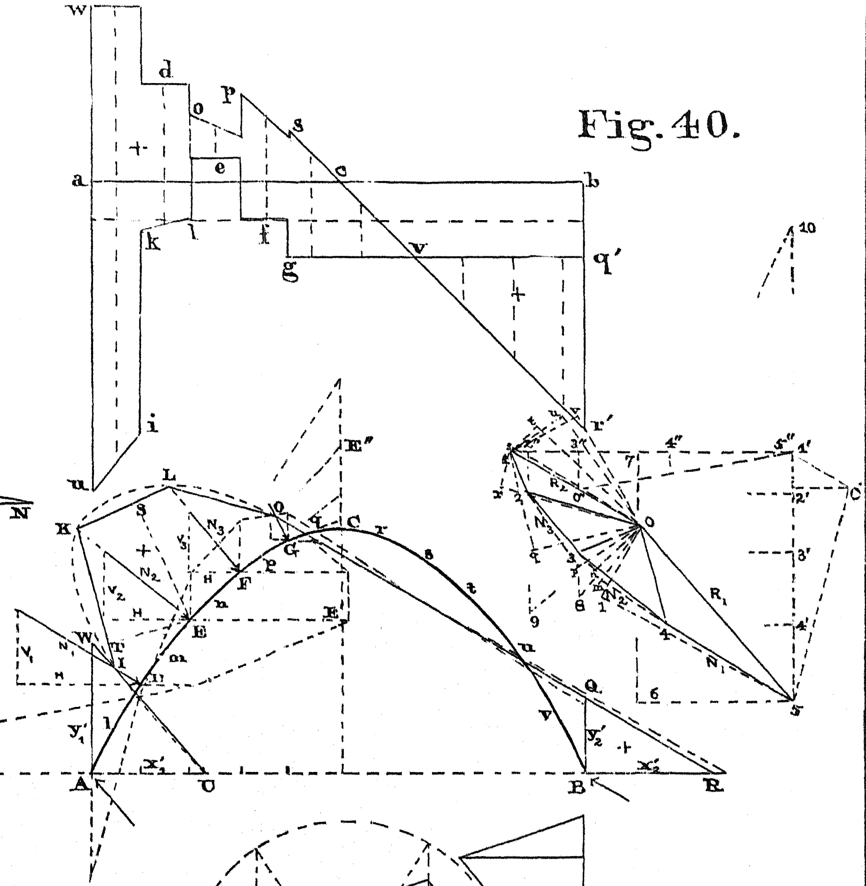

Fig. 40.

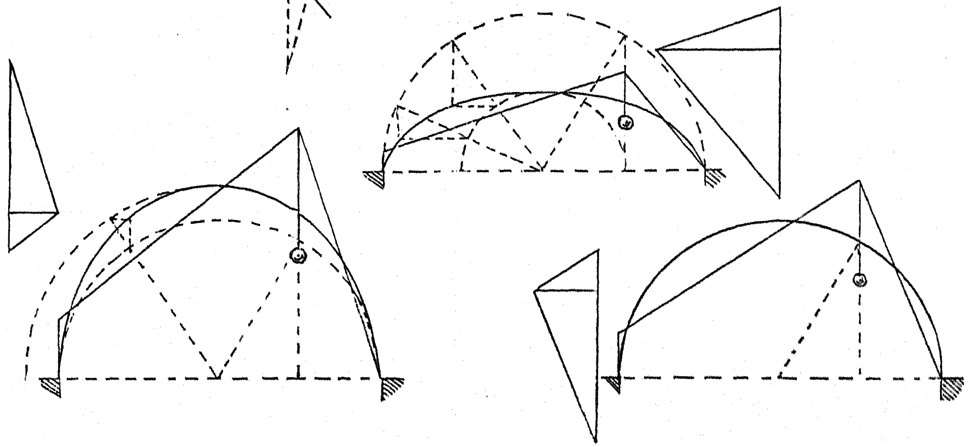

Fig. 43.

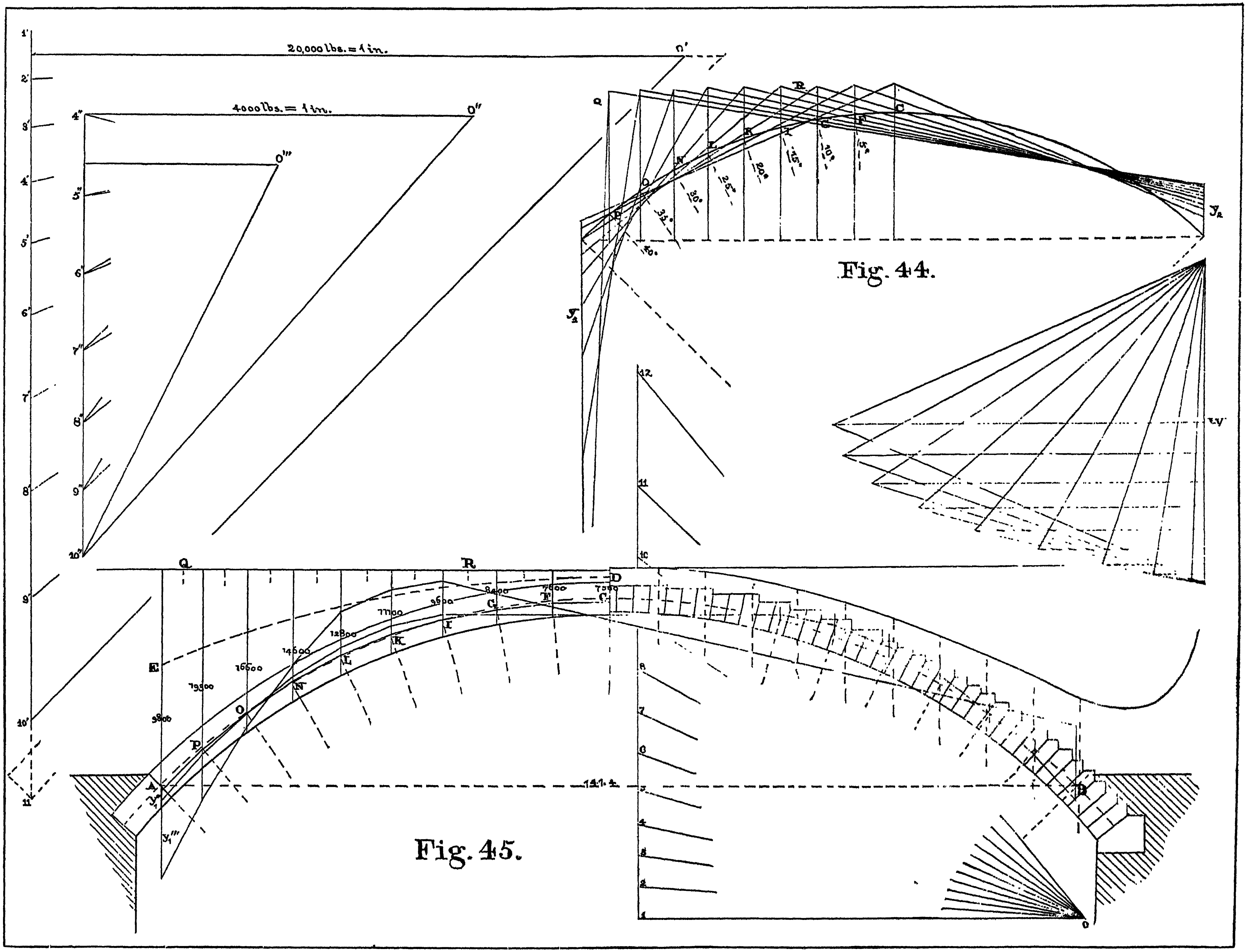
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Fig. 44.

Fig. 45.

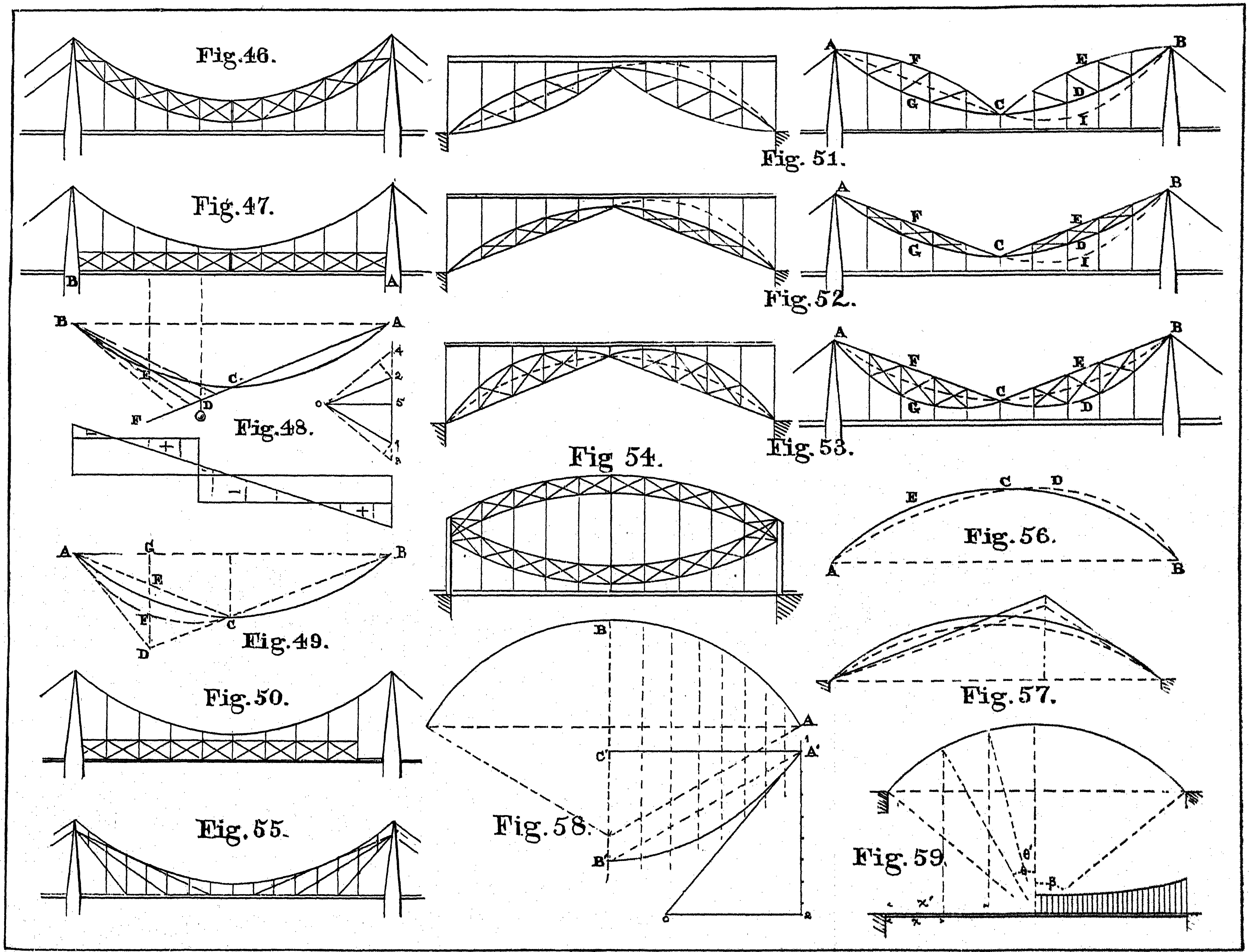
Fig. 46.
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Fig. 49.
Fig. 50.
Fig. 55.
Fig. 51.
Fig. 52.
Fig 54.
Fig. 53.
Fig. 58.
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Fig. 56.
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Fig. 57.
Fig. 59.

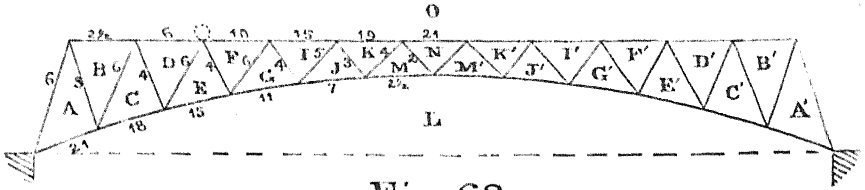


Fig. 60.

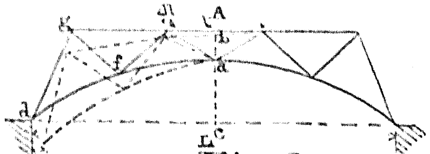
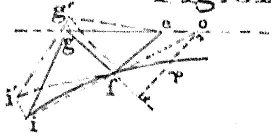


Fig. 61.



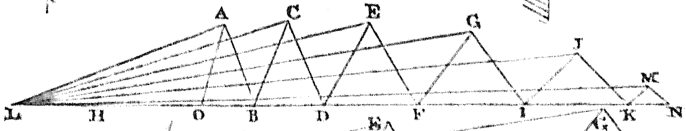


Fig. 62.

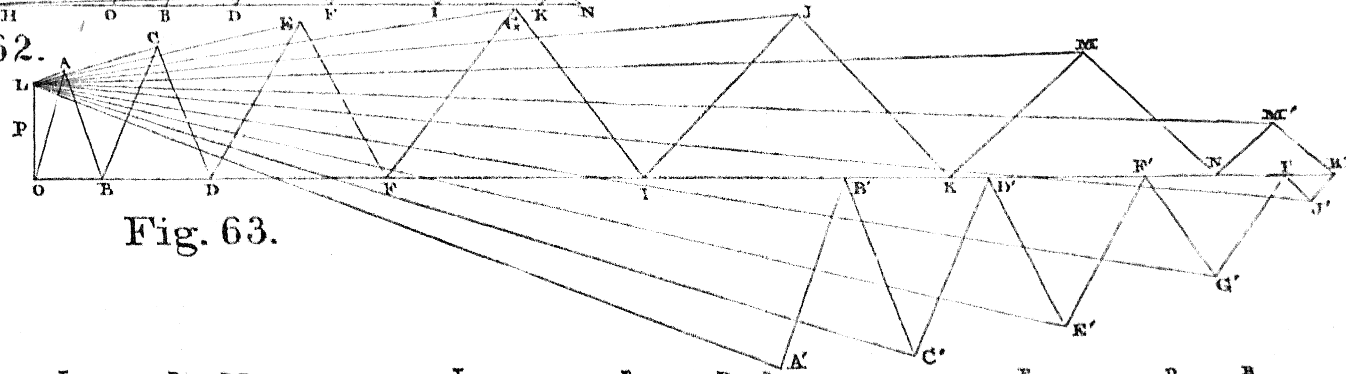


Fig. 63.

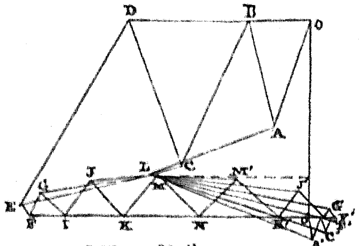
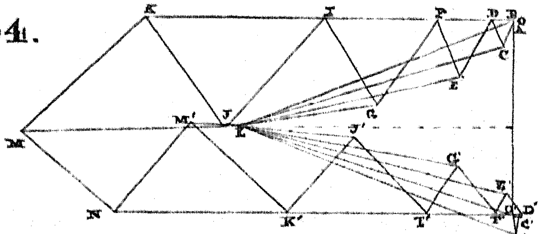
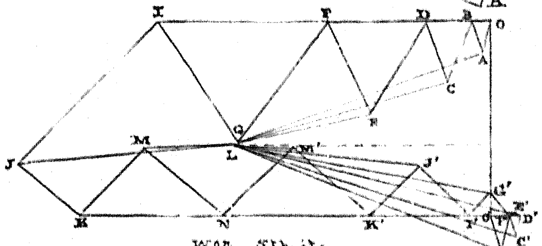
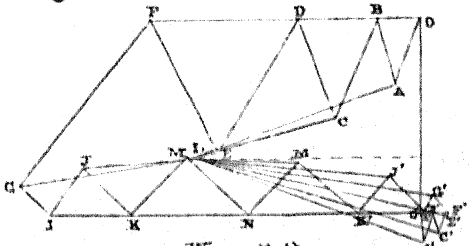


Fig. 64.







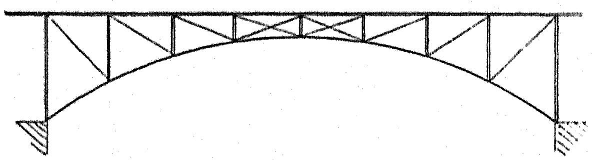


Fig. 65.

Fig. 66.

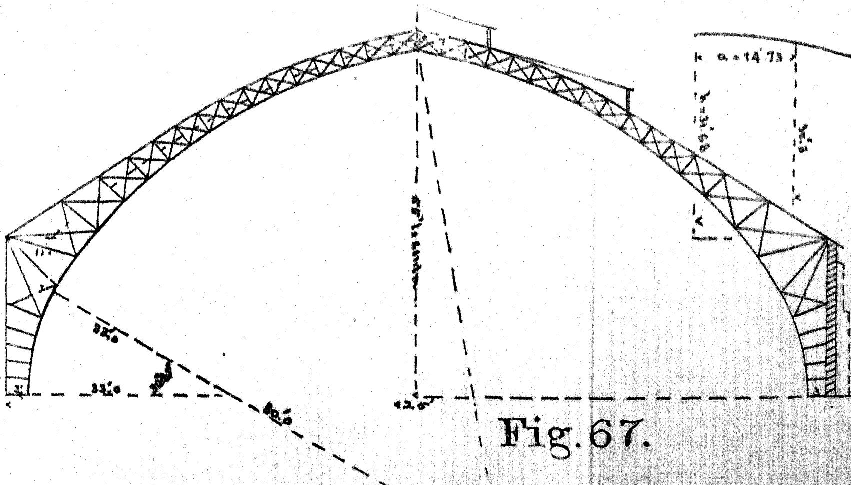


Fig. 67.

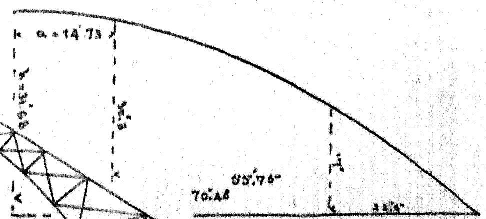


Fig. 68.

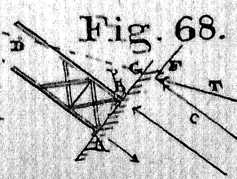


Fig. 69.

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